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ADDITIONAL APPENDIX

TO THE

OUTLINES

OF THE

FIFTEENTH CHAPTER

OF THE

PROPOSED GENERAL REPORT

FROM THE

BOARD OF AGRICULTURE.

ON THE SUBJECT OF

MANURES.

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CONTENTS.

No. I.

Plan *for ascertaining the Effects of the different Sorts of* **Manures** *in promoting* **Vegetation.** *By* **George Fordyce, M. D.**

It is known from experiment, that plants will grow in sand and clay, with the addition of distilled water and atmospheric air; and that after the plant has grown, if it be taken out by the roots perfectly clean, that the sand and clay are exactly in the same quantity as before the vegetation of the plant.

The whole of the nourishment of the plant, growing thus in pure sand and clay, is, therefore, taken from the water, or the atmospheric air.

It is farther ascertained by experiment, that certain substances being added to the sand and clay, the plant will grow more luxuriantly in all its parts, than if it had grown in sand and clay alone: the water and the atmospheric air being the same.

Substances which, when added to sand and clay, occasion a plant to grow more luxuriantly in all or any of its parts, are called manures.

Plants consist of roots, herbaceous stems and leaves, flowers, fruit, seeds. Certain substances added to sand and clay, are known by experience to make plants grow more luxuriantly, some in their roots, some in their herbaceous stems and leaves, some in their flowers, others in their fruit, and others in their seeds.

It is farther known by experience, that certain substances will have a very different effect in promoting the luxuriancy of plants when added to pure sand and clay, from the effect they will have when added to sand and clay with which other substances have been previously mixed. Or in other words, one manure will assist another in producing luxuriancy in the growth of the whole, or any part of a plant.

If one species of manure produces no effect when applied to a mixture of sand and clay unless another manure has been previously, or afterwards, employed, and if the manure which it is necessary to employ previously or afterwards, produces an effect whether the other had been employed or not, which effect is, however, greatly increased by the addition of that other manure, the effect of the one manure must be that of producing an alteration in the other manure, or some alteration in the plant, by which it may profit.*

All the experiments which have hitherto been made on the addition of manures to sand or clay, have been performed only in small pots, in such quantities as not to be at all applicable at large; or in some other manner, so that no certain conclusion can be drawn from them. All other experiments on manures, particularly those made by

*A manure may be itself the food of plants, or it may be of a kind that will bring other manures to a state adapted to their digestive powers, or it may excite in the plants themselves an operation, which may cause other manures to be digested, that otherwise would not have been, or may render an imperfect digestion complete. A buttock of beef, for example, yields essential food for man; but if a man had neither knives and forks, nor teeth, nor any other mode of cutting it in pieces, it could not be swallowed, and even if swallowed, it could not be digested in a weak stomach, unless pepper, or some other stimulant, were thrown in with it. Neither the knives and forks, the teeth, nor the pepper give nourishment to a man, yet without them, the beef, which gives the nourishment, could not be digested. Now the question, with regard to manures, when different sorts are mixed together, is, which of them represent the buttock of beef, which of them the knives and forks, and teeth, and which of them the pepper? One principal object of the proposed experiments is to decide this point, which authors are by no means agreed about, although it be the foundation of agriculture.

practical farmers, have always been upon sand and clay mixed with an unknown variety of other substances; and carried on without any attempt to investigate what these other matters were.

It is, therefore, proposed that some effectual experiments should be made upon sand and clay, mixed together in such proportions as may be rendered rich soil. For this purpose a field should be chosen, naturally consisting of such a mixture; known by experiment to be from one-fifth of clay and four-fifths of sand, to half clay and half sand. This is meant of the two earths perfectly pure. Such a mixture of sand and clay is sometimes called brick-earth.

The most eligible situation for making these experiments, should the Board of Agriculture think them expedient, is between three to six miles from London; or if nearer could not be procured, eight or ten. Nearer than three miles the air of the atmosphere is contaminated, so as to make great variation in the growth of plants;* it would be inconvenient to the members, at a greater distance than from six to eight, or ten at the farthest, to pay the frequent attention to the course of the experiments that would be desirable. It should also be at as great a distance as such a field can be conveniently procured from any village, and particularly a populous one, so that it may not be infested with sparrows, and that it may be out of the way of the curiosity of idle people.

Dr. Fordyce thinks an acre of ground would be sufficient to begin these experiments upon. It would be necessary to take off the whole of the present soil, as far down as it is at all altered by former cultivation; and it would require another acre to lay this soil upon; so that similar experiments might be carried on at the same time upon the earth already cultivated, either by natural or artificial means. These two acres might be in the middle of an inclosed field, perhaps of about five acres, in order that experiments might not be influenced in any way by inclosing hedges. The other part of the ground might be employed in any other experiment that might occur to the Board, such as the difference between dibbling, drilling, and broadcast, different successions of crops, &c. so that it would not be thrown away. He conceives a command of water necessary; and if a small stream should run through the field, it would be much more eligible, not only for the convenience of the experiments themselves, but also for shewing the advantages of irrigation, and the best method of employing it; at the same time, the field itself should either be naturally dry, or perfectly drained.

The surface of the ground from which the soil had been totally carried off, should be made into divisions; all of which should be perfectly flat, and should also have a path between them sufficient to afford an easy passage, without hurting the crops, which may be   feet.

The following crops might be cultivated:

Of the Gramina which bear farinaceous Seeds.

1st division. One bearing very heavy seeds in proportion to their bulk, which Dr. Fordyce thinks ought to be wheat.

2d div. The second a plant bearing seeds having a small proportion of farinaceous matter in proportion to their bulk; for this he would choose oats.

* As a proof that the air of large towns is not favourable to vegetation, at least to the bringing of plants to perfection, it may be observed, that very few plants will bear flowers in London, still fewer fruit, as may be seen in all the public gardens. There are some, such as the yellow rose, that will not flower within three or four miles of London. The great crops in the vicinity of that town, arises from the facility with which manure can be procured.

3d div. The next class should be the legumina, of which one division would be sufficient; and he would choose pease.

4th div. A plant containing farinaceous matter, or sugar, in its roots: there are several kinds of this description; those, for example, which have tuberous roots, which do not form a particular natural class of plants, such as potatoes, Jerusalem artichokes, &c.; of this class he thinks the potatoe most proper. It is not of much consequence which variety of the potatoe is planted, provided it be the same through the whole.

5th div. One of plants having tap roots; which likewise are of no particular natural class, such as parsnips, carrots, tragopogon, scorzonera, &c.

6th div. One of plants forming a root something between a tap and a tuberous root, but rather nearer the tap; I believe naturally all tap roots, containing only a very small proportion of farinaceous matter; the roots, for instance, of tetradynamia, such as turnips.

Such plants as are cultivated for their herbaceous stems and leaves; of which it would be sufficient to make one division for the gramina, and another for the legumina.

7th div. Gramina, any grass whose seed can be procured in sufficient quantity.

8th div. Legumina, sainfoin, or clover.

These divisions should all run from one side to the opposite side of the square acre.

Divisions should cross these, of the different kinds of manures.

1st div. The natural earth itself, without any mixture whatever, as a standard for the good or bad effects that other substances produced upon the several crops; for unless it be seen what such a mixture of sand and clay will naturally bear, it is impossible to know the advantage or disadvantage of any application that may be made to them by way of manure.

2d div. Putrid matter, as horse-dung, putrefied by itself, after it has served for a hot-bed, has been turned over when cold, and has lain for a month.

It would be best that this, like all the other manures in the first instance, should be mixed thoroughly with the soil at the time the seed is sown. Dr. Fordyce does not conceive this to be decidedly the best mode of application; nor does he think it best to apply the whole of any manure at once. Perhaps the most eligible method is that of the Japanese, which is to render substances putrified to a certain degree, almost fluid, and applying them in this state, at several different times during the growth of the plant, in the manner here called top-dressing; but as the ground may be occupied by the Honourable Board for a succession of years, in order to bring different modes of cultivation to certain experiment, he conceives it will be preferable, in this instance, to mix the manure with the soil before the seed is committed to the ground: the experiments may afterwards be varied, or they might be tried in different manners upon the remaining parts of the field.

3d div. The dung of animals not putrefied, such as cow-dung, which might be procured recent in sufficient quantity.

4th div. Vegetable substances not putrefied. The dung of graminivorous animals consists, in fact, of vegetable substances, having gone through the operations that take place upon food in the intestines of the animals, but not putrefied.

5th div. Animal substances rendered soluble in water, but not in the least putrefied.

6th div. Animal substances rendered putrid, such as pieces of meat mashed down very minutely, and kept in a sufficient degree of heat to render them perfectly soluble in water. All the above animal and vegetable substances are nearly free from any saline matter; and therefore in the first experiment, such animal or putrescent

substances may be neglected as contain saline matter, such as the dung of pigeons, sheep, &c. because in primary experiments the effects should be taken separately as much as possible; afterwards their conjunct effects may be made out by subsequent experiments.

The next class of manures is saline substances; of those, neutral salts are the first that should be tried. Of the great number of these, all of which may differ from one another, it will only be necessary to try one at first; and he would propose

7th div. Sea-salt, which ought to be rendered quite pure. Of the second class of salts, earthy salts.

8th div. Epsom salt, the substance contained in sea water and in the residuum of sea water, after the sea salt has been separated from it.

Other earths than sand and clay may fertilize the soil; but in the primitive experiments it may be sufficient to try calcareous earth in its two states.

9th div. Pure calcareous earth, or lime.

10th div. Calcareous earth, combined with gas or fixed air.

11th div. The last division should be of the natural earth only; but with this difference from the first, that the plants here should be constantly watered when the weather is dry.

All these applications should be equally applied, according to the manner above described, upon the acre upon which the soil of the other acre has been laid.

If a field were procured of five or six acres, Dr. Fordyce would also wish the sand and clay of a quarter of an acre to be cleared of cultivated soil, which should be laid upon another quarter of an acre, in order to try upon both the comparative effects of irrigation, or watering, upon the sand and clay alone; and upon the soil already containing animal and vegetable matters.

PLAN OF THE FIELD AS PROPOSED TO BE LAID OUT FOR EXPERIMENTS ON VEGETATION.

	Wheat.	Oats.	Pease.	Potatoes.	Parsnips or Carrots.	Turnips.	Gramina.	Legumina.
Natural earth.								
Horse-dung putrefied.								
Cow-dung not putrefied.								
Vegetable subtrances not putrefied.								
Animal sub-stances not putrefied.								
Meat putrefied.								
Sea salt.								
Epsom salt.								
Pure calcareous earth.								
Calcarcous earth with fixed air.								
Natural earth watered in dry weather.								

No. II.

The Substance of nine Lectures on Vegetation and Agriculture, delivered to a private Audience in the Year 1768,

By the late WILLIAM CULLEN, *M.D. Professor of Medicine in the University of Edinburgh;*

With a few Notes by GEORGE PEARSON, *M.D. F.R.S.*

INTRODUCTION.

AMONG the many arts to which Chemistry has been applied, with a view to promote their improvement, Agriculture has of late been thought one, and with justice: for it is evident, that without the aid of chemistry the principles of agriculture can never be fully comprehended. I have therefore for some time past been very anxious to have it applied to agriculture, that most useful of all arts yet known, how far successfully you gentlemen must determine.

I once thought of delivering some of the general principles, which I shall now offer to your consideration, in my public lectures on chemistry; but was prevented, partly because the time allotted for the duration of these lectures was too short; and partly because the greatest part of my students are bent upon another subject, viz. physic, to whom it would have been useless or disagreeable. Besides, this subject could not have been with propriety introduced into a set of chemical lectures, seeing there must always be something of a botanical and mechanical nature mixed with it, so that it could not be considered as strictly chemical. But the principal reason was the sense I entertained of the extreme difficulty of attempting to establish any principles of this art; and therefore, diffident of myself, I was cautious of making this system of mine too public, and have rather chosen to call a few of my friends, in a manner to a rehearsal of this essay; trusting so much to your candour as to expect proper allowance for small errors, and to your friendship, as to let none of any importance escape, without acquainting me with them.

Of the nourishing Matter of Plants.

The most obvious consideration of this subject is, that if a small seed is committed to the earth, and properly moistened, it springs up, and increases to a very considerable bulk.

From the soil in which the roots are placed, it seems chiefly to take its nourishment; and therefore it is presumed that in the soil there is some sort of matter which is the proper nourishment, or food of plants; this seems probable, seeing we must impregnate the soil with manures before it is rendered fruitful.* I shall now

* Although the situation in which plants live and grow, is generally in earth, which earth is rendered fertile or nutritive, by manure; it will be necessary for the right understanding of the most probable theory of nutrition, to be aware that perhaps neither *earth* nor *manure* contained in soil are

therefore endeavour to find out what this nourishing matter is; but, before I proceed to this, it will not be improper to examine whether this nourishing matter is the same in all plants, or whether it differs in different kinds of plants.

The diversity of vegetables is very great, and the difference of their qualities almost inconceivable; it is therefore difficult to conceive that the food of all this variety of plants should be the same, and much more natural at first sight, to imagine that there are various juices in the earth, almost as numerous as the different kinds of vegetables, each of which is the proper food of some peculiar plant, and of no other. But notwithstanding the apparent simplicity and perspicuity of this opinion, and the seeming difficulties that would attend the other, I am apt to imagine that the nourishment of all plants is the same, and that the variety of structure, consistence, tastes, flavours, &c. in plants, are all owing to the particular structure, and arrangement of the parts of the plants* themselves. Or if perhaps there are any different kinds of food,† (which I would not positively deny,) the diversity, is inconsiderable, and it may be looked upon as uncommon.

As this opinion is now adopted by some of the most knowing philosophers, it might perhaps be deemed unnecessary for me to produce any arguments to support it; but as some here may not have had an opportunity of hearing these arguments, and as bare assertions even upon the best authority, although they may perhaps gain credit at the time, do not convey to the mind that entire conviction which reason requires, doubts will be apt to arise in their minds, which may startle them a little, and give them uneasiness; for which reason I shall now recount to you some of the arguments upon which this opinion is founded.

1. The first that I shall take notice of, is, that when we examine soils by dissolving them in water (which seems to be the proper menstruum for this purpose, seeing all that plants can absorb is conveyed to them by this vehicle‡), all soils of whatever nature, and however different from one another, *contain only one impregnating matter.*§ What this common impregnating matter is, we shall have occasion to examine more properly afterwards. In the mean time we shall only observe that, although the different plants do affect different soils, and although it is no uncommon thing, to see one field covered with a great number of plants of one particular kind,

essential supporters of vegetable life and growth: for many species of plants in their usual or natural situation are nourished merely by river or other water, and atmospherical air, and perhaps every species whatever may be supported, although not vigorously, merely by these two substances impregnated with animal or vegetable matter.

* It is impossible to understand this argument without an acquaintance with the nature of chemical union, that is, union of different species of matter by virtue of chemical attraction or affinity. They who understand the nature of chemical union know, that *totally different species of things* may be composed by uniting variously with one another two or more given different kinds of bodies.

† As it is commonly admitted that different kinds of substances supply nourishment for the same and different species of plants, one may suppose that the respectable Professor probably here meant that by the powers of the vegetable œconomy, the same kind of nutritious matter is extracted from these various kinds of substances; and that from the diversity of composition of this nutritious matter, by the peculiarity of the vital powers of each species of vegetable, are produced the peculiar substances belonging to such different species of plants. This, however, does not appear to be the true meaning of the text; for the author afterwards says, putrefied matter in rain water is the sole kind of nutritious matter.

‡ Because it is conceived that matter in a solid state cannot pass through the absorbent pores, or vessels, of the roots of plants.

§ Certainly different kinds of matter impregnate soils; but it is presumed our learned teacher by "*one impregnating matter*" means "*one kind of substance only which is nutritious matter,*" as he explains page 6; namely, putrefied matter in rain and perhaps other kinds of water.

while another field adjoining to it, has none of this kind of plants upon it; but a great many of another kind, not to be found in the first; yet all this diversity seems rather to proceed from a difference of texture, and consistence, or perhaps of degree of impregnation of the soil, than from any variety of juices contained in it. Thus spurrey grows on a dry barren sand; and on the contrary, rushes love a stiff coherent soil. Some plants grow on a dry part, and others love a moist one; some grow only on the tops of walls, while others are to be found only in the bottom of ditches; some thrive best when exposed to the mid-day sun, while others delight in the shade. All this, however, we know to proceed from the texture, &c. of the soil, and not from any particular juices contained in it, fit only for one particular plant, seeing the same soil by changing its situation, &c. may be made to produce all the variety of plants to perfection, if it be of a proper moisture, consistence, &c. for the nature of the plant at that time growing upon it.

2. Another reason for supposing the nourishment of all plants the same, is that we see they will grow in any juice* that is presented to them, whether hurtful or not; for although plants have a sort of elective attraction, for some particular juices, rather than others, yet this is so weak that they do not seem to have a power of altogether rejecting any at all. Thus plants do not absorb so much spirit of wine as of water; yet they will take up as much of this or any other poisonous juice as will destroy them, and the common contents of all soils are of such a nature as will be absorbed most readily,† but

3. We may observe, that different kinds of nourishment would be quite unnecessary, seeing that all plants have the power of assimilating the juices they may imbibe, to their own proper nature.‡ That plants have this assimilating power is evident from the phænomena that occur in grafting or inoculating trees. Thus a graft or scion of one particular kind of fruit may be put upon a stock of another kind, and the juices taken in by the roots of the one be properly assimilated by the other; this is rendered still more obvious to the senses, by grafting trees of different species upon one another, as a pear upon a quince stock; in which case the juice rises from the ground to the place where it was grafted of the nature of the quince, but when it goes on further it is converted to the nature of the pear; so that it will have the same leaves, wood, flowers, and fruit, as any other tree of the same kind, grafted on a pear stock. This sufficiently shows that the vessels of trees have a power of converting the juices of one into another, as in this instance the juices of the quince were converted into those of the pear.

But the strongest instance of this assimilating power that I am acquainted with, is in the misletoe, which is a kind of vegetable which has always its roots lodged

* M. de la Baisse found, that plants which grew in solution of madder were coloured red; and Mr. Bonnet found those which grew in ink were coloured black.

† The meaning of this paragraph does not appear to us very obvious; perhaps Dr. C. means us to understand that liquids, however variously impregnated, can be absorbed, but that only one kind of matter in them is nutritious. Some persons may conceive that it is just as reasonable to suppose, that the different kinds of fluids which can be absorbed may contain different kinds of nutritious matter; for although the same kind of substances be nutritious to different plants, and the matter which is composed from them by the vegetable œconomy, may be of different kinds in different plants; it is also certain, notwithstanding Dr. C.'s assertion, that different kinds of substances are nutritious to the same kind of plants. If mint grows luxuriantly in water containing flesh, it also grows luxuriantly in water containing starch; but starch and flesh are totally different species of things.

‡ Different plants can assimilate the same nutritious matter to the respective nature of each different species, but they have also this power of assimilating different kinds of substances.

in the bark or wood of some trees. It is commonly called the misletoe of the oak, but improperly, as it grows more readily upon almost any other tree than the oak. This then converts the juices of the trees upon which it grows into that of another kind, altogether different from them in leaves, wood, flowers, and fruit.

Hence, therefore, since we do not discover different juices in the earth, since plants have not a power of rejecting any that is presented to them, and since they are endowed with the peculiar property of assimilating all innocent juices into their own nature, I think we may safely conclude that the food of all plants is the same. The proving of which will considerably shorten our labour, as it will prevent our inquiring what might be the different substances that are the food of different plants. I go on, therefore, to consider what this common food of plants is.

There has been a variety of opinions concerning what this nourishment of plants is; some holding that earth, air, fire, water, &c. together or separately have been this pabulum of plants; but as it would take up too much of our time to examine each of these several opinions, I shall content myself with delivering my own opinion on this subject, which is, that this pabulum is *nothing else but pure rain water.**

That rain water alone can nourish plants is evident, seeing that almost all plants, by a proper management, can be made to grow by it alone: the germination of every seed can be carried on by means of this to a certain degree, and can be easily carried so far as to produce all the peculiar juices of the plant which it maintains. If the seed of an aromatic plant is sown, the plant raised will be an aromatic, and so on of other kinds of plants. It is indeed difficult to make many plants produce flowers, or fruits, or seeds, in pure water alone. One set of plants, however, produce all these in it most readily, and it is probable that by a proper management, a great many others might be made to produce the same. And Mr. Du Hamel, of the Royal Academy at Paris, has preserved an oak with its root in water, for eight years together, by no other artifice than changing the water frequently; the oak increased in bulk, and branches grew out like any other oak. He found indeed that towards the end of that time it did not vegetate so fast as at first, but this was not owing to want of nourishment in the water, but manifestly to a disease of the roots, as was easy to be perceived. The experiments of Dr. Woodward, Mr. Boyle, and others who have examined this subject, all tend to confirm the same; and the famous experiment of Van Helmont, relative to this, is so well known to every one, as to make it unnecessary here to repeat it.† From all which we might with safety conclude that water is the food of plants.‡

* The Professor afterwards explains that rain water probably is nutritive not as pure elementary water, but as impregnated with putrefied animal or vegetable substance, which yields the pabulum of plants. Rain water also is always impregnated more or less with the gazes of the atmosphere, especially with oxygen gaz, and a very minute proportion of saline and earthy matter, as the experiments of the accurate and judicious Margraaf inform us, and as might be inferred from the circumstance of water falling through the atmosphere to the earth.

† This experiment of Helmont has been so often quoted, and affords so leading a fact, that it must be satisfactory and gratifying to the curious to have it related in the literal version of the author's own words. "But I have learned by this handicraft operation, that all vegetables do immediately proceed out of the element of water only; for I took an earthen vessel, in which I put 200 pounds of earth that had been dried in a furnace, which I moystened with rain water, and I implanted therein the trunk or stem of a willow tree, weighing five pounds; and at length five years being finished, the tree sprung from thence did weigh 169 pounds and about three ounces; but I moystened the earthen vessel with rain water or distilled water (always when there was need), and it was large, and implanted into

This is so far well; but we are not obliged to stop here, seeing some late experiments, have gone farther, particularly these of Mr. Bonnet of Geneva. He observed, that when the roots of plants were allowed to float loose in the water, they became diseased, being filled with tumours, &c. which prevented their absorbing the nourishment properly. This he imagined proceeded from the little resistance that the roots received from the water, and therefore thought if any method could be contrived to filter this water slowly to the roots of plants, while at the same time these roots met with a proper resistance from the substance in which they were placed, that then the plants would arrive at a greater degree of perfection. With this view, he tried a great many substances, as flax, cotton, sponge, sawings of trees, &c.; but moss, as being the least subject to putrefaction, was found to answer best. In this manner he raised oats, barley, wheat, beans, and others, to as great perfection as in the best garden mould, which was put into pots of the same kind, and the same species of grain was sown in them. A grain of barley sown in the garden mould, produced thirty-two, in the moss fifty-three, and the other plants almost in the same manner; all the grains sown in the moss were later in ripening than in the earth, which he attributed to the greater vigorousness of the plants. He raised, in the same manner, flowers of different kinds, which were, in every respect, as fine, and were possessed of their natural odour, in as great perfection as those laid in the earth. Fruit-trees he also raised, in the same manner, and reaped from them excellent fruit; as raisins, prunes, &c.; and he even found that this might be employed with advantage, in some cases, in place of earth. Orange-trees, which were beginning to decay, when taken from the earth and planted in moss, recovered their vigour; and a vine, in the space of a few months, which was planted in moss, sent out shoots more than ten feet in length, which carried eight large bunches of grapes, of an excellent flavour. From these facts, he, with a great deal of seeming justice, concludes, *that water contains the food of plants, and that earth is only useful to them as a filter, to administer it to them in a proper manner.**

There is, indeed, one observation that would seem to disturb this theory, viz.—that some soils will not yield a crop without manuring; from whence it might be alleged, that these manures supply the soil with the nourishment of plants, of which it was destitute before; which could not be the case if water was their proper pabulum. This, indeed, if it was always found to be the case, would disturb our general pro-

the earth; and, lest the dust that flew about should be co-mingled with the earth, I covered the lips or mouth of the vessel with an iron plate covered wtih tin, and easily passable, with many holes. I computed not the weight of the leaves that fell off in the four autumnas. At length I again dried the earth of the vessel, and there was found the same 200 pounds, wanting about two ounces.—Therefore, 164 pounds of wood, bark, and roots, arose out of water only." (Page 109, Van Helmont's Works made into English, by J. C. of Oxon, fol. 1664.)

‡ Although plants cannot live without water, they also cannot live without air, and, we might safely add, not without animal or vegetable mucilage, at least not in a healthy condition, and which therefore may afford nourishment as well as water. This is not inconsistent with the Professor's doctrine, which is, that rain water is nutritious in as much as it contains putrefied matter.

* These important and elegant experiments of Bonnet, certainly, are almost decisive, that neither earth, nor what is commonly understood by manure, is essential to the support of vegetable life; but do not demonstrate that water alone affords nourishment; 1. Because the atmosphere may furnish a great variety of nutritive substances, viz. oxygen gaz, nitrogen or azotic gaz, carbonic acid gaz, besides hydrogen gaz, and animal and vegetable matter. The atmosphere may also furnish substances which are not alimentary, but which render other things more nourishing; such as salts, earths, &c. 2. The water, in Bonnet's experiments, might have contained animal and vegetable mucilage, and pretty certainly salts, earth, and gazes.

position; but so far is this from being the case, that we find some soils that can be made to carry crops almost perpetually, without the addition of any manure whatever. Now, in this case, we would expect to find a great proportion of vegetable food in the soil; and as this must be soluble in water (seeing nothing coarser can enter the roots of plants) we would expect a great proportion of these soils would be capable of being dissolved in that element; but, upon trial, we find that they are not soluble in it in greater proportion than many other soils that are not endowed with this quality of perpetual fertility. Hence it still appears probable, that water alone is the food of plants, and that the fertility of these soils is occasioned by a peculiar texture of parts, by which they are enabled to administer the water they receive, in a proper manner, to the roots of plants.*

Again, we can render soils fertile for a very long time, by the application of manures which we know are not the food of plants; as marl, which if laid upon the ground will impregnate it and render it fruitful for fifty years; and yet this marl, alone, is a poison to plants. It would, therefore, seem natural to imagine, that those manures render the ground fertile, by altering its texture, and making it more proper for administering the water to the roots of plants.† The horse-hoeing husbandry lately introduced by Mr. Tull, which consists wholly in breaking and dividing the soil, seems likewise to owe its effects to the same cause, and not, as Mr. Tull himself imagines, by reducing the earth itself into such small parts as to enter the roots itself.

From the whole of these observations, I think we may, with the greatest reason, conclude that rain water is the food of plants, and that breaking the ground very fine is only of advantage as it serves to give a more easy passage to the roots, and make it a more proper filter for the water.

Rain water is prepared by the Creator, and sent down upon us sufficient for all the purposes of the husbandman, and therefore he need give himself no trouble any further; but if any more curious should inquire whether it was pure elementary water that furnishes food to plants, or whether it was only in consequence of its being always impregnated with some matter inseparably connected with it; to them I would answer, that it appears to me probable that *it is water impregnated with something that furnishes this pabulum, and not the pure element alone.* If they should still go further, and inquire what this impregnating matter is; I would answer, probably

* According to the observations contained in this paragraph, what are called manures do not really afford nourishment; they are only to be considered as aiding nutrition from rain water. If certain soils can yield a given kind of crop almost perpetually without manure, and which do not appear to contain more animal or vegetable matter from the plants in the soils, than other soils which cannot carry the same crops repeatedly without further manure of animal or vegetable matter, besides that which is from their own plants; these facts only prove that such manures serve not only to nourish plants in certain circumstances, but in others to render different things nourishing, namely, by applying duly, or enabling the plant to receive, nourishment from water, air, and the impregnations of water and of air. For there are conclusive observations to prove, that plants do generally absorb, and are nourished by the solution in water of animal and vegetable matter of manures, as well as by rain water. Dr. Woodward, as the author himself quotes in the next page, found waters to be nutritious in proportion to their putrescency, *i. e.* in proportion to the quantity of animal or vegetable matter which they contain; and direct experiments show, that animal or vegetable matter is absorbed from water by plants growing in it, and that they grow more luxuriantly in it than in pure water.—Further, contrary to Tillet's experiments, Hassenfratz found plants would grow only for a short time in pure water and earth alone.

† The *rationale* here given of marl, seems just; at least, its principal effect is not that of supplying nourishment. It may also operate by stimulating. Mr. Kirwan, however, imputes to earth a nutritive property.

animal or vegetable substances decomposed and subtilized by putrefaction, and in this state carried up by the water in the state of vapour. Many substances are raised from the ground, along with the water, which are again let fall before they rise to a great height; but this substance is so intimately blended with it, that it remains inseparably united with it, and we only know that it is there present by the water being liable to putrefaction: and, I conjecture, that it is in consequence of its presence that water nourishes plants, from the experiments of Dr. Woodward, by which he found that the waters which were most liable to putrescency were best adapted for nourishing vegetables.*

Animal and vegetable substances are usefully employed as manures; and, from what has been said, a doubt might arise, whether they did not produce their effect as manures in consequence of their supplying the vegetable with food. That they may sometimes produce a small effect in this way, I shall not venture positively to deny; but, if they have any influence in this way, it is far from being considerable, and their principal effect seems to be owing to the alteration they produce upon the soil as a filter; for the putrefaction has not been carried on to a sufficient length to produce this effect, and it is probable that, as soon as it is sufficiently attenuated for this purpose, it is carried off in vapour.†

It would be a matter of no use to inquire, what animal or vegetable substances are most proper to impregnate water for the purposes of vegetation, seeing all of them, when decomposed by putrefaction, become so much alike as not to be distinguishable from one another; and probably, therefore, all are alike in this respect.‡

It might here be proposed, as a query, whether all rain water is sufficiently impregnated for the purposes of agriculture, or not? and were I to answer to it, it would be in the affirmative. It is possible there may be a difference of impreg-

* Our great Professor could not possibly have imputed the nutritive power of rain water to the solution of putrefied animal and vegetable substances, if he had either been acquainted with the experiments of *Margraaf*, or had evaporated to dryness pure rain water *i.e.* collected at a distance from towns, and after the atmosphere had been washed by long-continued rain, for then he would have known that such water is almost as pure as distilled water, and does not contain an atom of animal or vegetable matter. Further, if impur rain water be nutritive from its impregnation, then other things are nutritive also, in so far as they contain water and animal or vegetable matter, which is inconsistent with our teacher's doctrine. Dr. Woodward's observation is nevertheless just; of course, water most disposed to putrefy, must contain the greatest proportion of animal or vegetable matter, and, hence, be most nutritive; but this militates against the doctrine of rain water containing the sole food of plants.

† No mechanical alteration in soil can alone account for the effects of manures of animal or vegetable substances; for a similar texture of soil, produced by substances which are not animal or vegetable matter do not produce the same fertility, and the same fertility is frequently produced by animal or vegetable matter in soils of very different kinds of texture. It is not meant, however, to deny, that animal and vegetable mucilages do not also influence vegetation by altering the texture of the soils; which they certainly do, by giving to some a due viscidity, and to others a due degree of friability. But the principal effect of mucilages, in all cases, is to furnish, by solution in water, the principal food of vegetables. Putrefaction is no ways necessary, either to dissolution, or nutrition. Our Professor's fears of the escape in vapour are groundless.

‡ Here our learned Professor supposes two things which, it is apprehended, will not at this time be allowed to be facts.—1. That putrefaction is necessary to render substances nutritious.—2. That animal and vegetable substances are alike when in a putrid state. But it is certain that solution of fresh animal or vegetable mucilage in water is absorbed, and nourishes plants. And Mr. Bertholet has shewn how different animal and vegetable substances are, in point of composition; the former essentially containing azote or nitrogen, but the latter only in some kinds of plants is found to be a constituent part: which discovery may justly be ranked as the most important that has been made this century concerning organized matter.

nation of rain water, at different times and in different places; and, therefore, one may sometimes be a little better for the purposes of agriculture than the other: but as I imagine this difference, if any, is very small, it can produce very little effect; and, from the experiments which have been made, all of them are capable of nourishing vegetables. Dew is always reckoned a very great promoter of vegetation; and, perhaps, it may be owing to its being more impregnated than other water, as it has not been raised so high. It is always more putrescent.

Having now, as I imagine, sufficiently proved that rain water* alone always contains the vegetable food, I shall next go on to inquire in what manner rain water ought to be applied to vegetables, so as to produce the greatest effects possible.

Of the most advantageous Mode of applying the Food of Plants.

Water is absorbed by vegetables by their leaves and roots, but principally by their roots; wherefore it is the proper application of it to these that I shall first consider.

The vegetation of a plant above ground bears always some proportion to the extent and number of roots below ground; therefore, the first step to the promoting the vegetation is, to increase or multiply the number of roots.

Roots are of different kinds, and, according to their form, are called *bulbous*, *tuberose*, or *fibrous*; which require a different management from one another.— These are again divided, according to their position, into horizontal and perpendicular; but whatever is the form of the root, it is always from the small fibres that

* No doubt rain water contains "vegetable food," because water appears to be essential to the support of plants, and because it contains, in its ordinary impure state, animal or vegetable matter, which is also an essential part of the nourishment. Plants, also are no where found without the contact of air, and on withdrawing it they soon die; this is the case even with plants which grow under water. It has been lately supposed that charcoal, or carbon, separated from animal or vegetable matter, is the principal food of plants; but we believe there is no evidence of this substance proving nutritive but when it is united to hydrogen and oxygen in vegetable matter, or to hydrogen, oxygen, and nitrogen in animal matter. With equal justice might hydrogen or oxygen be considered to be the principal food of plants, for they cannot subsist without them; but probably they also only nourish when united together constituting water, or when united to carbon constituting vegetable matter, or when united to carbon and nitrogen constituting animal matter, or when oxygen is united to carbon constituting carbonic acid. Notwithstanding our extreme respect for Mr. Kirwan's judgment, we cannot but express our surprise that he should adopt the doctrine of Hassenfratz concerning the carbonic principle. With regard to water, it probably serves two purposes in vegetation, viz. 1. That of being a vehicle or menstruum of solid matters; and, 2. That of supplying the plant with a part of its hydrogen; for water appears to be decompounded by vegetation in the solar light, as Hales long ago, and of late Dr. Ingenhousz, has shewn by decisive experiments; so that its hydrogen remains behind, entering into the composition of the vegetable matter, while the oxygen, in the state of gaz, is separated from the surface of the leaves. We believe that no plant, and no animal, can be nourished without animal or vegetable matter, water, and respirable air; although some philosophers have affirmed, that water and air only are necessary to the life of many species of plants and animals.—Whether other matters besides the three just mentioned are essential to the support of life, such as earth and salt, we shall not proceed now to attempt to explain. These observations consist perfectly with Mr. Young's experiments, which show, that the fertility of soils is as the quantity of hydrogen gaz, or rather as the quantity of carbonated hydrogen gaz, which they afford; but the quantity of this gaz must be as the quantity of animal and vegetable matter, or nearly so.

the plant receives its nourishment, and the growth of the plant is in proportion to the quantity of these fibres.

It was formerly imagined, that roots absorbed moisture at all parts, and that it was filtered through the pores of the bark; but it appears more probable, from late experiments, that they absorb the moisture from the earth only, at the extremities of these fibres.

Mr. Bonnet, of Geneva, made many experiments, with a view to determine this question, by making plants absorb water tinged with coloured liquors, which he calls injecting; by which means he discovered that it entered the extremities of the fibres, and was conveyed through the bark to the leaves; nor did it enter at any other part of the root, unless it had been wounded. He has several other observations on this subject; for a particular account of which I must refer you to his own works.

Mr. Du Hamel has likewise made experiments on this subject, which led him to the same conclusion. He has likewise endeavoured to trace the progress of the roots, and has found that they advance in length at the extremities, and that when they are once formed they remain ever in the same place, without any progressive motion, except at the points; and from his observations he has reason to conclude, that it is only at the extremities of the roots they absorb their nourishment, as has been already said.

The utility of this œconomy is obvious, and truly admirable; for the large branches of the roots remaining without motion, preserve the tree steady, and carry the nourishment to the trunk, while the smaller ones, provided with mouths to receive nourishment, move about in quest of it.

The leaves of bulbous-rooted plants, he found, were extended only at the lower part, while those of all other kinds were increased along the whole length, but largest towards the extremities.

From Mr. Du Hamel's experiments, we likewise learn that, when the roots are cut through, the vegetation of the plant is stopt for some time, till the wound is closed up, and new roots are pushed out from that one, which never fails to be the case, but that then they vegetate more vigorously than before; and in this case the roots always assume an horizontal direction, and the root that was cut remains in its place without any motion. From this observation he draws several conclusions of great use in the cultivation of trees, &c.

I have said that roots absorb nourishment only at their extremities; but this must not be taken in the strictest sense: for the absorbing power seems to extend about one-twelfth of an inch from the point; which part of the root seems to be divided into a number of small capillary tubes, forming a sort of brush, which seems to contain the mouths for receiving the nourishment. Mr. Du Hamel has found, that if this sort of brush is not cut wholly off, the vegetation is not stopt; and to the want of this brush he attributes the stoppage of the absorption, when the large roots are cut off.

From the foregoing observations it appears, that roots absorb nourishment only at their extremities; the greater the number of these, therefore, that they have, the vegetation will be the quicker.

Our next business, therefore, shall be to inquire into the most proper method of multiplying the extremities of the roots.

The formation of roots, and indeed the whole progress of vegetation, depends originally upon moisture. The necessity of this for the formation of roots is evident from a number of observations, which would be tedious here to mention. I shall

only here remark, for this purpose, that if roots are cut, and placed where they have plenty of moisture, new roots are sent forth from every bud, or eye, whereas, if they were planted in a dry place, no new roots would be formed; or, if we could so contrive it as to have a piece of earth kept constantly moist in the midst of some that is dry, it will be found that the roots extend themselves in this with great freedom and ease, whereas they scarcely ever enter into the dry earth: these remarks may sufficiently show the use of moisture to the formation of roots.

Another circumstance absolutely necessary to the formation of the roots, is an easy penetrability of soil, to allow them to push out with freedom; and it seems to be chiefly owing to this cause that some plants will grow among pure sand, if they are supplied with a sufficient quantity of water.

These two circumstances are all that are necessary for the formation and enlargement of roots; but for the multiplication of them, others are to be attended to. In soils where the resistance is very small, if they are kept moist, the roots extend to a very great length, but have very few mouths; and where the resistance is very small, as in pure water, this is not only the case, but the roots breed tumours and ulcerations, &c. which do not allow them to convey to the plant, in a proper manner, the nourishment that is absorbed by the few mouths that there are; which was the case with Mr. Du Hamel's oak we mentioned,* during the last six years of its growth, in which it languished.

Resistance, of a proper degree, therefore, is necessary to the multiplication of roots, and the increase of their mouths.

This is prettily illustrated by a set of experiments made by Mr. ——, and recorded in the Memoirs of the Royal Academy of Paris for the year 1739. He planted a variety of seeds in soils differing in degree of consistence and penetrability, gradually increasing from the softest, as cow-dung kept constantly moistened, to the hardest indurated clay; and he found that, in these soils that were most easily penetrable, the roots extended to the greatest length, and that they had always a greater number of ramifications in those soils of a firmer consistence. He likewise found, that the vegetation above ground was always most luxuriant, in those soils that were endowed with a considerable degree of resistance.

Mr. Du Hamel has likewise remarked the same; observing, that when a root in its progress meets with a solid body, as a stone or piece of hard earth, it is stopped in its growth, and pushes out lateral shoots in great abundance; but if the soil be very stiff, the roots are sometimes stopt, and, being unable to produce lateral shoots by reason of the great resistance, a kind of nodus is formed at the extremity of the root, and its mouths being thus wholly shut up, it becomes useless for the purposes of vegetation, and the plant must of consequence perish.

Too much resistance in a soil is, therefore, of the worst consequences to vegetation.

But all plants are not equally hurt by the same degree of resistance in the soil, some requiring a very tender, soft soil, to make them thrive, while others are able to penetrate the stiffest, and thrive upon them; hence, therefore, the reason that the soil must be finely prepared for producing some plants, while it can be made to carry others with much less labour.

The roots of oats require, and are able to surmount, a greater degree of resistance in the soil than those of wheat and barley, and therefore it will live where the others

* The oak grew eight years in water.—During the first two years, it grew more vigorously than is usual in a good soil; but after this, although it produced fine leaves, it did not increase, but diminished every year.—*Mem. de l'Acad.* 1748.

would perish. The giving the due degree of cohesion to the soil that is proper for the different plants he cultivates, is, therefore, the principal business of the husbandman.

From what has been already said, it would appear that loose soils in general would be most proper for vegetation, if the roots were by any means increased to a sufficient number. It has likewise been observed, that cutting the roots of plants produced this effect; therefore we would naturally expect (where other circumstances are favourable to it) that the most luxuriant plants would be produced in soils kept constantly tender, and having their roots frequently cut: this the horse-hoeing husbandry seems to perform; and this may serve as an explanation, in some measure, of the wonderful effects of this practice, when properly conducted. It is from this principle likewise that we must explain the reasons of a practice, lately introduced with success into Switzerland, which consists in drawing a machine through their corn-fields, after they are advanced a considerable length, so formed as to cut a certain depth without turning over the soil. This cannot, surely, in many cases be compared to horse-hoeing; but, as it is easily performed, it may be of use in many cases, especially in very rich and easy-penetrated soils which do not require opening; it which case it might, with proper management, perhaps, by some be disputed which had the pre-eminence.

Nearly the same effects are produced by pruning vegetables above ground as by cutting their roots; and the connection between these two parts of the plant is so strong, that one cannot be injured without making the other suffer; and was this a proper place, we might show the very strong analogy between the roots and branches of vegetables, the one being most readily convertible into the other, if their situation be changed; but I must refer you to Mr. Du Hamel for satisfaction in that particular. I shall only here observe, that he has endeavoured to show that trees very often lose the small part of their roots during winter, in the same manner as branches do their leaves. It is, however, certain, that the vegetation of plants may be stopt by depriving them of their leaves, in the same manner as by cutting their roots; and any plant, by being very often deprived of its leaves, as well as by too frequent cutting of the roots, may be entirely destroyed. Pruning, however, if properly timed, and cautiously performed, may be often of very great advantage to vegetables; but how far it agrees with cutting the roots, and in what particulars it differs, I shall not now inquire.

This peculiarity of the vegetable economy may sometimes be employed, by the farmer, with advantage, and, as I imagine, might in a particular manner be usefully laid hold of, on some occasions, to promote the tillowing or stocking of corns, with very great advantage.

The tillowing of grain is a subject too little attended to by the farmer; and the principles upon which it depends but very little understood. I shall, therefore, suggest what has occurred to me as the cause of this phenomenon, hoping it may be useful, at least by making others examine it with attention.

This, then, I would allege always depends upon some check in the vegetation.* Cold, when the plant is not advanced too far, promotes that. Stiff soils, if in a con-

* The *rationale* of the operation of cold upon plants is analogous to that upon animals, viz. its causing an augmentation of the vital principle or irritability; in consequence of which, when the stimulus of heat is applied by the coming on of warm weather, &c. animal action and vegetation are proportionally considerable.

dition to nourish plants in a sufficient degree, are more remarkable for this than any other; both of which, in some measure, prevent the quick vegetation of the plant; and frequent cutting of the leaves, before it has shot up, produces the same effect. The tillowing of grain, therefore, always is occasioned by the vegetation being checked, and may be promoted by skilfully cropping the plants; and hence the reason of that practice, so common in England, of eating down their wheat by sheep.

This is useful for causing the grain to tillow, not only by cutting the plants, but also by consolidating the earth, which will promote this. It is likewise of advantage for checking the over-luxuriancy of the crop, and hastening the harvest. And, upon the same principles, we are to account for a practice, common in this country, of cropping with a sickle the leaves of these plants that appear to be too luxuriant.

One other circumstance is necessary to be taken notice of, as influencing the tillowing of plants, viz. that the roots be properly formed. The plants, of which we are now speaking, when in a proper state, have always three distinct kind of roots. The radicle, which goes directly downward, when the plant begins to vegetate.—The plume, which rises upwards, and afterwards forms the stalk: upon this last, there is a knot, from which it sends out a third set of roots, called horizontal from their position, which always are so. Some time after this knot is formed, there is commonly another formed, with fibres also; and the vegetation is never perfect without these two knots. These horizontal roots, after they are of a certain age, fail, and others come out in their place; and it is at these knots that the plants tillow: and, in order to give it an opportunity of doing this well, it is necessary that the plant be not too deep; for, if it is, it shoots out only one stalk, and never more.

The different effects produced by the same operation, in different species of vegetables, is a subject well worthy the observation of the curious; and I shall not fail to suggest every hint on that head that occurs to me. Of this nature is the one I am about to mention. If the leaves of potatoes are cut over when they are young, and the stalks afterwards cut again and again, it makes the fibres of the roots to swell prodigiously, but it does not at all increase the bulb: on the contrary, they are hardly formed at all. Hence, I imagine that the swelling of the bulb below ground depends, in some measure, on the ripening of the seed above ground: whether or not this is the same in all bulbous-rooted plants, I cannot say.

Having now endeavoured to ascertain what is the food of plants, and shewn the manner in which they absorb this nourishment; our next business shall be to consider what is the most perfect soil; and the manner of bringing one that is not so into a state of fertility.

Of Soils, and the Manner of rendering them fertile.

All plants absorb nourishment by their roots, and therefore moisture is necessary to the growth of them all; but some plants are endowed with so strong an attractive power in their leaves, that they can by that means subsist where their roots have very little moisture; as on the tops of walls, &c. But although they may live, yet they never arrive at any bigness, unless their roots are extended to some moist place. Water must, therefore, be applied to the roots of all plants that are in a thriving condition; but, unless it be to aquatics, it must be applied by the interposition of a solid body. Water is present in almost all the bodies that we know. It is to be found in stones of all kinds; it is present in the most obdurate clays, that have the

appearance of so much rock; it is especially present in all manner of soils, although seemingly dry or friable; as also in all manner of animal and vegetable substances; but it is not from every one of these that plants can attract it: there is none that can attract moisture from stony substances; few that can attract it from indurated clays; and most part of plants require a looser soil, and more moisture, than this affords. And were it not for the resistance that is necessary for the formation of the roots of some plants, the moister a soil was, the more proper it would be for the nourishment of vegetables; but as this resistance is necessary, a soil endowed with a moderate degree of solidity, will be the most proper for nourishing vegetables. As, therefore, few plants require either pure water or indurated clays to live in; I shall inquire what substance is most fitted for bringing a soil into a moderate degree of solidity, so as to be best fitted for the purpose of agriculture and vegetation.

Upon examining the variety of ingredients of soils, clay seems to be best fitted for this purpose; for clay is the only earth that can absorb and retain moisture in its pores, without appearing in its fluid state: but if the water is applied in too large quantities, the clay that was at first diffused in it will subside to the bottom, and there concrete into a solid mass, which, if sufficiently dried, will become quite impervious to moisture. Hence, therefore, clay, notwithstanding the advantages it has in some respects, can hardly furnish a proper soil for most plants, of itself, seeing it will sometimes be so moist as to become almost fluid, and at other times so dry as to crack and become hard and impervious to moisture, like a rock. Clay, therefore, of itself, cannot be looked upon as a perfect soil, but may perhaps serve as the basis of it, forming this when mixed with other substances. This has been frequently imagined by writers on agriculture; and sand has, by many of them, been supposed to be the only ingredient necessary for the purpose. We shall examine this opinion a little.

Sand, considered as a soil, is almost directly the reverse of clay, in every respect. Clay absorbs moisture, and swells it to a considerable bulk, retaining it closely, and not suffering it to filter through it. Sand admits the water between its pores, but is not expanded thereby, and allows it to filter through it most readily. Clay, after it has been moistened, becomes coherent and solid. Sand remains in its former incoherent state, without any alteration. Hence it has been imagined, that by mixing sand with clay its bad qualities will be obviated. It will allow the water to filter through it more readily; be more easily broke into pieces by the plough, and more pervious to the roots of plants, &c.

But I very much doubt whether all these effects will be produced by this mixture alone; nay, I am apt to imagine, that in some cases it may be rendered worse by this addition; for pure clay, if it is exposed to the air, readily cracks, and in time falls into powder, by the wetting and drying alternately; whereas, if it is mixed with sand, it is not liable to be affected by it in the least, but remains one uniform hard body, without being affected by the variations of the air; as is sufficiently evident in making rules for chemical vessels, or common clay-mortar to houses, brick, &c.; so that sand does not seem to answer the purpose of dividing the clay, but rather the reverse.—It, however, may be made to have some effect upon the clay, if the sand is mixed in very large proportion; but in that case they are very ready to be separated from one another, by the washing of the rains; the clay being washed from the sand, and the soil left poor. Hence sandy soils are always most ready to be impoverished. I therefore would conclude, that the mixture of sand and clay, alone, does not afford a perfect soil.

That the clay in a soil is impregnated with some other substance besides sand, before it can be rendered fruitful, is evident, seeing we can very easily separate the clay from the sand, and, when this is done, the clay in the fruitful soil is different from pure clay, in a great many respects; it is always of a darker colour, and more friable consistence, than pure clay; it admits of water more readily, when dry; parts with a superfluous degree of moisture more easily; and is with more difficulty made to part with the whole of its moisture, than pure clay. Hence it would seem, that the clay of soils is impregnated with some other substance than sand, before it can be rendered fertile.

Was it necessary to illustrate this more clearly, it might be sufficiently evinced by tracing the different processes by which a pure clay may be brought from that state to a perfect soil without the admixture of sand, which is so sufficiently obvious, as to render it unnecessary to say any thing further to bring this under your consideration. The instances which every one of you must have seen will readily present themselves to you.

I have attempted, by art, suddenly to effect this, which is usually the work of time and nature, and find that pure clay may be made to approach very near to the nature of a soil, by the mixture of mucilaginous substances with it, in sufficient quantities. These substances appeared to me most likely to answer this purpose from a number of considerations, but particularly from observing the singular property with which they are endowed, of retaining very strongly a certain quantity of moisture. Thus, *e. g.*—If a small piece of gum tragacanth be dissolved in water, it allows the water to evaporate from it fully, till it becomes of a certain consistence, after which the moisture is evaporated very slowly, and it is very long before it becomes perfectly dry. This so much resembles the case of a clay soil, that I was induced to try it, with success. Mucilaginous substances, therefore, are the necessary impregnating bodies in soil.*

Should we inquire what mucilaginous substances are proper for this purpose; the answer would be easy, seeing they all agree in this property, and therefore are all useful, and all animal and vegetable substances are proper manures when properly applied.

A mixture of clay and sand, with animal or vegetable substances added to it, forms therefore a perfect soil. There may, however, be other resources for this mucilaginous substance, as rain water, dews,† &c. by the proper application of which this soil may properly be formed.

Having thus endeavoured to show the composition of a perfect soil, I shall now go on to mention some of the distinguishing characteristics of what I understand by a perfect soil.

A perfect soil is that which can contain the greatest quantity of water without becoming fluid; does not become easily viscid; readily absorbs water when it is dry; and, if at any time it receives too large a proportion of water, it readily parts with the superfluous moisture, but retains a small proportion very strongly, and, when it is perfectly dry, does not become hard and coherent, but friable and crumbly.‡

Hence, therefore, it is little subject to be hurt by the vicissitudes of the weather, and always allows a ready passage to the roots of plants.

* Although mucilaginous matter may serve vegetation mechanically in the way here described, there are many facts showing that its principal use is by itself supplying nourishment.

† See notes * and †, p. 7, which furnish the objections to this observation.

‡ A soil of this description can only be considered as the most proper for particular plants; for different plants require different kinds of soil.

Having premised this much, in general, of soils; we shall now go on to consider the varieties of these, and point out the causes of these varieties.

Soils differ from one another according to the proportions they contain of these ingredients which we have supposed useful ones in their composition, the variation in which respect may occasion a very great diversity of these. But soils very often contain a great many other substances, which cannot be considered as useful ingredients; they will be therefore different, according to the kind of substance, or quantity of it, they contain. I shall briefly mention some of these substances which are most commonly found in soils, which I would consider as useless and foreign to a proper soil.

First, then, the fibres of the roots of plants may be looked upon as foreign to a perfect soil.

These are in some degrees present in almost every soil which has ever carried any plants before; for as the roots of plants extend to a very great distance, and are so small and tender as to be easily broke off when the plants are taken from the ground, many of them must remain in every soil which has ever carried plants before. But although these are so common in soils, they are not at all necessary to the formation of a perfect one, as I have made a soil that was very perfect without any of these in its composition.

It is pretty remarkable, that these fibres alone will make a soil; that is, a proper place for plants to grow in, as may be seen by Mr. Bonnet's experiments which I have already mentioned. But, in order to make them answer this purpose, it was necessary that they should be pressed together very firmly, and regularly watered, which could not be practised on a soil in the ordinary method of managing it. We have some soils, however, that are pretty purely of this kind, as is the case with all the mossy soils, these being almost wholly composed of the fibres of vegetables; these absorb or retain moisture very readily, but in a different manner from clay. Water is absorbed by mossy soils in the same manner as by a sponge, which is retained in the pores of it in a fluid state, and may be readily squeezed out of it.—This is far from being the case with clay, which seems to unite intimately with the water, and never allows it to remain in its fluid state. But as this is the case with mossy soils, they are best adapted for the nourishment of aquatic plants.*

Secondly, I would here consider calcareous earths as being sometimes an useless ingredient in soils. This is very frequently present in them, in small quantities, as used as a manure; of which I shall speak more at large when on the subject of manures. It is sometimes present as the product of putrefaction;† but in both these cases it is only in very small quantities. At present, I mean only to take notice of it when in too great proportion, as in chalky soils. In these it seems to have, in a great measure, the same effect as sand in a less perfect degree; for when mixed with clay, it forms a very viscid mass.

Thirdly, Selenites, is found in almost every soil, and may be considered as an unnecessary ingredient. It is surprising to see what quantities of it there are in some soils, and may be expected, in some degree, in all, as the vitriolic and calcareous earth, of which it is formed, are both present in almost every soil.‡

* Therefore the fibres of roots for some plants are useful in soil.

† The quantity of calcareous earth separated by putrefaction is too trifling to merit attention, either as an useful or hurtful ingredient; it being only an extraneous matter in animal and vegetable mucilage.

There is reason to believe that calcareous earth possesses stimulating qualities to the plant, as well as acts mechanically.

‡ I know not on what authority the Professor asserts, that selenite, that is sulfate of lime of the new system of chemistry, is contained "in almost every soil." A great deal has been of late said,

In what manner this may act, I cannot easily say. It may perhaps have some effects as a saline substance, and diffuse the water more entirely; but we cannot suppose that its effects in this light can be great, as it is so difficultly soluble in water. Where it is in large proportions, as a hard and solid body, it may act in much the same manner as sand.

Fourthly, Salts, of one kind or another, are to be found in the greatest part of soils, but these are only found in so far as they are separated by putrefaction, and therefore in very small proportions.§

Fifthly, Oily matters, of some kind, are also found in almost all soils, but these are likewise only there present in consequence of putrefaction. Much has been talked of these, and little understood.*

Sixthly, Metallic substances are likewise found in almost all soils, and may be looked upon as an unnecessary ingredient.†

There may perhaps be some variety in this respect, but iron seems to be the most universal. This is present, in some degree, in all soils, and copiously present in almost every clay, and tends greatly to increase its viscidity, as all the indurated clays contain a considerable proportion of iron. I attribute this effect in general to the iron, without being able to say in what manner it may act. It is found in the state of an ore, and of a vitriol.

If it acts in the last state, it should operate as a saline manure.

I go on now to consider

The different kinds of Soils, and Methods of distinguishing them.

I shall here follow the common methods of dividing, and examine the reasons of each as I go along.

One very common division is, into *heavy* and *light* soils. This heaviness, or lightness, is usually estimated from the quantity of moisture, or the degree of resistance, that the soil makes to the roots of plants; both of these effects will be occasioned by the quantity of clay in these soils, for this detains the moisture, and, in certain circumstances, resists the roots more strongly than any other soil.

and some pieces written, on the effects of this substance as a manure; but although it may be of use in certain soils, and for some plants, its good effects have not been experienced as were expected.

Meyer, in 1768, contrary to Dr. C. asserts, that it is a valuable manure; and it has been used, it is asserted, with signal success, in Switzerland, France, and America. Perhaps its mode of operation is principally mechanical.—It may also act as a stimulant to the plant. Its effects, as a promoter of putrefaction, are doubtful; nor must it be admitted as a nutriment.

§ The remarks in note *, page 8, apply here.

* There is but little chance of oily matter in soils, as produced either by the growth or decay of vegetables and animals in them; but writers have published their dreams concerning the wonderful fertilizing effects of oil; which effects experience has not shown any where to have been produced, and which it is contrary to reasoning from physiology, chemistry, and natural philosophy, to expect.

† In small quantity it is not improbable that metallic salts may be of service by stimulating the plant, but much danger is to be apprehended from an over-dose. The sulfate of iron, or salt of steel, is the only salt of this kind expected to be present. In the state of oxide, which the Professor calls ore, it is in every soil, I believe, without exception, and in considerable proportion in all brick earth soils: it is the cause of the redness of such earth, when burnt to a stony hardness, in the forms called brick-bats, tiles, &c. In this state of oxide it does not appear to be active upon plants; its mechanical action upon the earth, with which it is mixed is, perhaps, principally worth consideration.

Heavy soils are again distinguished, into the *stiff*, and *strong*. The stiff are those that are always tough and viscid, and make a great resistance to the roots of plants; which is always occasioned by a quantity of iron mixed with the clay. The strong are likewise of a considerable weight, but are not so viscid as the stiff, nor give so much resistance to the roots of plants, and are always of a more dry and crumbly nature, and are remarkable for their very great fertility. These properties of the strong soils are always owing to a quantity of mucilaginous substance in their composition.*

With regard to light soils, these are always more dry and crumbly, or friable, than the others; which is always occasioned by their having a large proportion of sand, calcareous earth, or selenites, mixed with them. That which is occasioned by the sand is most common.

Gritty soils ought here also to be taken notice of as a division of the light soils different from sand. A gritty soil is one filled with the fragments of broken stones. These grits are of very different sizes; some of them being full of large stones, almost as big as a man's head, while in others you will not find one larger than a nutmeg.

These are very often formed by a concretion of clay and iron, which look like so many stones, and are constantly generated and destroyed in the soil. Some are formed of calcareous earths, and a great variety of other substances.

Between these two extremes of sandy and clayey, there are a great variety of soils, all of which are commonly known by the name of loams, or loamy soils. I find that these soils that, in gardening, are known by that title, approach much nearer to the nature of sand than clay, as they contain much more of it than the other loamy soils, are perhaps less liable to accidents, and may therefore, by giving a surer crop, yield at a medium as much as clay soils do, but there is no instance of a soil of this producing such large crops as some of the clayey soils have been known to produce. Some by a loamy soil mean only such a one as produces very luxuriant crops. If it is taken in this sense, it will admit of a very great variety.

Soils have also been distinguished into dry and moist, which may be owing to a variety of circumstances.

This may be occasioned by the position of the ground, or by having too much clay in its composition; which last is usually one of the causes of this fault; but this is not always the case with clayey soils, for if they are properly mixed with mucilaginous substances, a clayey soil may be dry enough. The depth of a soil likewise makes a considerable alteration in this respect; the deeper it is it will always be the drier. Soils are also different in this respect, according to their bottom, and a clayey bottom always tends to produce wet in the soil; for when clay has got leave to subside long without being stirred, it concretes into a solid mass, quite impervious to water; so that the water, after it has filtered through the soil, is prevented from sinking downward, and made to pass off between the clay and the soil, which must keep it wet. A sandy bottom, of consequence, tends to make the soil dry, which is likewise the case with a rocky bottom, for this allows the water to

* The stiffness may be merely from the small proportion of other earths mixed with clay, as well as from the oxide of iron. Perhaps much should not be imputed to mucilage, in considering the mechanical qualities of clay soils, for, in fact, the evidence of its presence is doubtful in many cases, and in others it is in too small proportion to produce the effects here mentioned, which may seemingly be more reasonably referred to the mixture of sand and calcareous earth. If mucilage, however, be present, no doubt it will increase the fertility under favourable circumstances.

filter through the crannies and chinks that frequently occur in these rocks. Other circumstances will also tend to make a variation in this respect. Thus, if the soil has any tendency to moss, it is easy, from what has been said, to see that it will be wetter from that cause; for it will absorb the water more plentifully, and always retain it in a fluid state.

Soils have likewise been distinguished into cold and warm. These I take to be the same with moist and dry, as the moist soils are always cold, and the warm soils always dry, which is easily accounted for. The warmth in the soil must either proceed from the heat of the air, or from a subterraneous heat contained in the earth itself, or from both. A moist soil has all its pores filled with water, whereas those of a dry soil are filled with air; now as air is much sooner heated than water, a moist soil will be longer of being brought to the heat of the air than a dry one, and therefore, in the spring of the year, it will remain much longer cold, and consequently be later in its produce, than a dry one, and thus it will get the denomination of a cold soil. The same reasoning would suffice, if we should suppose a subterranean heat, with this difference only, that, if that should be allowed, the difference of bottom would produce a greater effect than in the other case.

These are the common distinctions of soils. I now proceed to point out the manner of examining soils, and distinguish them one from another.

Of the Manner of examining Soils.

Many are the ways by which soils are distinguished from one another, often very vague and uncertain. The best method in this, as almost in every thing else, is to do it by accurate experiments, which will often prevent us from being led into errors.

Thus, if we have a soil that is of a tender and friable nature, it may be occasioned either by a mixture of sand or of mucilaginous substances. To know, therefore, what proportion of each of these it contains would be desirable, as it would enable us more properly to estimate the value and qualities of our soil; and this may be obtained by proper experiments. For this purpose, take a quantity of the soil you mean to examine, dry it thoroughly, and weigh it; lixiviate, or wash it in warm water, in sufficient quantities, allowing it to remain a sufficient time to dissolve the mucilage, and assisting it by agitation and the other assistants of solutions; and after properly separating the water, by filtration or otherwise, and drying thoroughly, and then weighing again, the diminution of the weight from what it was at first will show the proportion of mucilage it contained. In this operation, care must be taken that the whole of the mucilage be dissolved; for it is often very intimately connected with the clay, and difficultly separable from it.*

* Instead of this tedious, and inaccurate method of ascertaining the quantity of mucilage, as the Professor himself is sensible of, perhaps the method of distillation in the naked fire is preferable, as the quantity of carbonic acid, hydrogen and azotic gazes afforded, would be as the quantity of mucilage; but care must be taken not to confound the carbonic acid of calcareous earth with that from mucilage, which may easily be avoided. Mr. Young has very ingeniously inferred, that the fertility of soils is as the quantity of hydrogen gaz which they afford; and this gaz must be in general as the quantity of mucilage; but the carbonic acid should also be reckoned. Where great precision is required, it will be proper to use both the method of *solution* and of *analysis by fire*.

To know the proportion of sand, or clay, contained in any soil, we must take advantage of the diffusibility of the clay, and separate it from the sand by elutriation.

This is done by pouring water on the whole mass, and diffusing it through the water, and then allowing it to remain for some time to subside; the sand being most weighty, will fall to the bottom, and the clay may be poured off from it along with the water: this operation should be repeated as often as necessary; and then the parts, being dried and weighed, readily show the proportions of each.

Care must likewise be had in this operation not to mix the sand with the clay; for the finer parts of the sand take a long time to subside.*

The quantity of calcareous earth contained in a soil may be determined in the same manner as that directed for finding the proportion of mucilage, only employing acids instead of water, as these dissolve the calcareous earths alone.† The vitriolic acid is not proper for this operation, as it only corrodes the calcareous earth, but does not dissolve it.—Any of the other acids may be employed, in their dilute state; but, if they are much concentrated, they will sometimes dissolve some of the clay.—In that state, therefore, they ought not to be used.

These are the methods of examining the contents of a soil by chemistry.

Besides these, there are a great many other methods of judging of soils, more easy, and generally less accurate; which I shall now mention.

The first of these methods of examining a soil, that I shall mention, is by its *friability*. By friability is meant, the tendency of a soil to crumble readily into small pieces; and the smaller these pieces that it falls into are, it is esteemed the more friable. To swell, when exposed to the air, is likewise sometimes a property of this soil; but this is not at all essential to it; for this is only the case in those soils which owe their friability to a quantity of mucilage, and not to those rendered so by sand.

The *colour* is likewise often employed as a means of judging of a soil. Clay, in its pure state, is of a white colour, but, when mixed with putrefied animal or vegetable substances, it assumes a blackish colour; and therefore, when it is of this colour, proceeding from this cause, it may always be esteemed a good soil; but if it proceeds from a mixture of moss, it will do harm.

As to the other colours of clay, these are of a very great variety; as reddish, brown, yellow, blue, &c.—All these, except the blue, I suppose, are owing to a quantity of iron‡ being mixed with them, differing in the degree of colour according to the quantity of iron contained in them.—But what the blue is owing to, I cannot say. It does not seem to be owing to iron, as several of these blue clays burn white in the fire.

Sometimes the colour of a soil is produced by the sand in its composition. This, in its pure state, is a transparent crystalline mass; but is always almost, in some degree, coloured, owing to the admixture of some metalline matter, or earthy sub-

* Where great accuracy is wanted, the soil should be digested in sulphuric acid, and the proportion of clay will be as the quantity of alumn composed; for clay, combined with sulphuric acid, produces alumn.

† If both clay and calcareous be present, they may be dissolved out by digesting the soil in muriatic or nitrous acid, and the earths in the solution may be separated from one another by several different methods familiarly known in chemistry. During the solution, the quantity of carbonic acid extricated should be noticed, as it will serve to estimate the proportion of calcareous earth.

‡ Not properly iron, but oxide or calx of iron.

stance.—This may be of all variety of colours, and may influence that of the soil very much. Hence, therefore, this method of judging of a soil must be inaccurate, seeing the colour may be varied by so many causes. But it is in general a good rule—the blacker the soil is, it is the better.

Another method of distinguishing soils, no less sure, and far more easy than the first, is by observing the plants that naturally grow upon such soils. There are plants adapted to every soil whatever, upon which they grow and thrive with greater vigour than any other; and although every plant will admit of some variety of soils upon which it will live, yet it is only on some certain kinds of soils that they arrive at their greatest perfection. This, therefore, if carefully attended to, might be of the greatest use in this respect. I have many observations on this subject, but as I could not be rightly understood but by those who have a considerable share of botanical knowledge, I omit them at present; and shall content myself with assuring you, that whoever studies botany with the view of acquiring the knowledge of soils, will receive very great satisfaction from it.

This finishes what I had to say, with regard to the method of examining soils. We have formerly endeavoured to show what was meant by a perfect soil, and the methods of forming one. It is but rare that such can be found, and, even when it can be got, it requires, for the most part, a good deal of art to preserve it in that state. Our next business, therefore, shall be to point out some of the methods of preserving a perfect soil, supposing such a soil given.

Of preserving Soils.

All soils, in which there is a considerable proportion of clay, would, if left to themselves, naturally concrete into hard and solid masses, unfit to allow the roots of plants to penetrate it.—Nature, by her operations, tends in some measure to counterbalance this tendency in the soil, and art can be very properly called in to her assistance.

The chief means employed for this purpose may be reduced to four heads:—

1. Mechanical Means,
2. The Operation of Heat and Cold,
3. The Action of the Roots of Plants, and
4. Of Animal and Vegetable Mucilages.

Of each of which I shall speak in order.——

1. *Of mechanical Division of the Soil.*

Under this head are to be ranked all the various methods of ploughing, harrowing, &c. At the best, these can only be looked upon as rude and imperfect operations; and the division by this means can never have any considerable effects, unless it is frequently repeated when the ground is in a dry, friable state, so as to allow it to break and crumble down into small pieces; for if ground is ploughed wet, it is only cut into several long and narrow pieces, which remain as stiff and coherent as before ploughing, and therefore this can be of no service, but on the contrary must do harm; for the clay when kneaded by the feet of the cattle, while wet, remains firm and coherent after it dries, whereas, if it was left to dry of itself, it would be divided into

cracks and flaws, so as to become in some measure pervious to the air; and when ground has been trodden, and thus rendered firm and solid, it is much more difficult to divide again.—On all which accounts, ploughing ought never to be performed when the ground is wet. These effects, however, are less strong on light than on clayey soils, but are, in some degree, felt in all. This much I thought necessary to say concerning the mechanical means of dividing a soil. I now go on to consider the second head; which was,

2. *Of the Operation of Heat and Cold upon Soils.*

When a clay mass has been a little concreted, and afterwards a sudden heat is applied, it becomes very crumbly, and falls down into smaller parts, which is effected by the heat suddenly rarefying the air contained in it, and dissipating the watery parts, which, by forcing a passage for themselves to the surface, divide the mass into small and minute parts: and hence it is that heat pulverizes. Without the assistance of heat and cold, mechanical division would have very little effect, as it would always leave the soil in large solid masses, very different from the crumbly mould necessary for vegetation. Neither can heat or cold produce their full effects upon a soil, without the assistance of mechanical division; for when the ground is left in its natural state, a very small surface is exposed to the air, and it is only on that surface that the vicissitudes of the temperature of the air can take effect.

But the surface is so much enlarged by ploughing, that the soil is much more affected by this means; and, even after it is once ploughed, the masses are so large, and the moisture in the heart of these so great, that it would be long before the heart of it could be affected by this means.—Hence, therefore, it is necessary that the ploughing be frequently repeated, to expose the whole of the soil to the influence of the sun and air, and thus make it reap the greatest advantage. This is one of the principal ways in which fallowing meliorates the ground.

These are the effects of heat and cold in a moderate degree, which are produced chiefly in the summer season, when the soil is dry; but the effects of cold, when at a certain degree, is no less remarkable and great in the winter season, when the ground is wet.—The power of frost, in this respect, is obvious to the most superficial observer, and the manner in which these effects are produced is now so generally known, that some here will perhaps think it unnecessary to observe, that it is produced by the great expansion of the water at the time of freezing, by which means the particles of earth are separated from one another very minutely, and with a surprising degree of force; and in this manner the soil is very much meliorated.

But it sometimes happens that the frost, by penetrating too deep, remains very long in the ground; by which means it keeps the soil extremely cold, and prevents the vegetation in the spring, and thus produces very bad effects upon the crops: and as snow prevents this, it is always an useful concomitant of frost.—But the effects of snow depend, in a great measure, upon the manner of its going off the ground; if it is dissolved slowly, it produces its full effect, but if it is suddenly melted, and accompanied with rains, it frequently does hurt.

3. *Of the Action of Roots of Plants in dividing the Soil.*

This is perhaps one of the most powerful (though least attended to) methods of dividing the soil. The roots of plants spread out into innumerable distinct fibres, by which they suck up their nourishment from the earth. These plants, therefore, during the time that they are growing, will be always dividing the soil in a very minute manner, and with a force different in different plants.

The common kind of grain cultivated here push out their roots only with a very small degree of force, and therefore the soil must be considerably loose, otherwise they will not thrive; but there are some kinds of plants that push out their roots with a surprising degree of force. I have seen roots penetrating through prodigious resistances. Walls are sometimes overturned, and rocks split, by the roots of trees; and hence, these roots must have a considerable power in dividing the earth.

The power of herbs in dividing the soil, is different at different periods of the growth of plants.—For when the plant is vigorously pushing out stalks and leaves, the growth of the roots is then proportionally strong, and it is then that the accurate division of the ground is made; but when the leaves begin to fail, and the flowers begin to decay, and the plant approaches to maturity, then the roots also stop in their motion, and no longer divide the soil by their extension, and from that time it begins to subside and concrete into a solid mass as before.

But this division of the earth is not the only rise of the roots of plants; they likewise assist in preserving a due moisture in the earth. For so admirably has nature fitted vegetables with a power of self-preservation (if I may use the phrase), that the leaves and roots mutually supply one another with moisture according to their needs. For if a plant is put into a soil that has too little moisture, it will absorb a great deal by its leaves, which passing from thence to the root will make the earth more moist; whereas if another plant of the same kind is put into another quantity of the same earth properly moistened, the absorption by the leaves will be little or nothing at all, and the soil will not become more moist, but rather drier, as the leaves in this case perspire and throw off the superfluous moisture. Hence, therefore, while plants are growing upon a soil, the earth will always be kept in a tolerable degree of moisture, which must be of very great advantage to it.

But there are certain plants whose leaves begin to fail as soon as the flower is formed, and go on gradually diminishing in their growth till the seed is ripened, when they are entirely decayed; so that the earth will receive no advantage from these plants during that period of their growth. This is the case, in some measure, with all the cerealia, but more frequently with the culmiferous kinds, as wheat, rye, oats, barley, &c. in which class of plants this order of vegetables never fails to take place, and the effects upon the soil are exactly as we have supposed. For if we examine a soil where any of these plants are growing, it will be found to be always moist and tender before the ears are formed, but after that time it grows gradually drier and drier till the plant is ripened, at which period it is quite dry and hard, if no other vegetable has grown along with them.

This course, however, does not take place with all plants; for there are some that after they are brought to bear seed in one place, still continue to send out leaves at another place, which will absorb moisture from the air; and thus roots continue to push forwards, so that the earth is always kept moist and friable, and therefore

they do no harm to the ground. These plants which follow this course are called leguminous kinds, as pease, beans, thetch, clover, sainfoin, lucerne, &c.; in all of which the vegetation is never stopt till the seeds are perfectly ripe, or the cold of the season pinches them and stops their circulation. Therefore we distinguish the crops that are sown into the *impoverishing* and *meliorating* crops; all these of the culmiferæ being reckoned impoverishing, and the legumina meliorating.*

These are the two kinds of crops that are sown in every part of the globe. And here I cannot help observing how careful the God of nature has been to provide every thing for the ease and conveniency of man; a very striking instance of which is now under our consideration.

For it is observed, that if a soil is once in order, so as to produce crops, it might be for ever kept in that good order, by properly alternating the crop, from some of the culmiferæ to the legumina every year, without any manure whatever.

This is not a vain chimerical notion, but is founded on observation and experiment. I have seen the experiment fairly tried twice. One gentleman kept a piece of ground in this manner twenty years, without any manure at all, and had always good crops. Another gentleman tried it twelve years, with the same success; and the experiment, in both cases, was only discontinued by the death of the several owners.—But they were long enough continued to show the probability, if not certainty, of the fact advanced.

There is another general rule with respect to plants which deserves to be taken notice of, viz. that all the plants which we cultivate for the sake of their roots are meliorating crops—such as carrots, turnips, &c. if not allowed to come to seed; but if they are allowed to ripen, their seeds are as much impoverishing as any of the culmiferæ; as was long ago observed by the celebrated Mr. Tull.

Not only these, but even the culmiferous crops themselves, become meliorating, if not allowed to come to seed. A crop of wheat, or barley, cut green, will improve the ground as much as any of the legumina.

Among the enriching roots, the potatoe may be reckoned one; but I believe the same may be said of this as of the others—that if it was allowed to stand till the seed was ripe, it might be reckoned among the impoverishing crops. The bulbs are never produced as our potatoes before the seed is formed, and are not perhaps at their perfection before the seed is ripened. This never happens in this country; but it is probable the nearer they approach towards it, they will impoverish the ground the more. We commonly allow our potatoes to stand long in the ground, in order to make them large. But I suppose it would be more advantageous to take them up sooner; for although the quantity of potatoe might be smaller, yet the ground being more enriched would fully recompence it.

Another particular worthy to be taken notice of is, that all perennial plants must be good for the ground, as they are always increasing in leaves and roots, so that they perpetually keep it in some measure moist and tolerably divided by their roots; and this, I suppose, is the principal good that grounds can get by resting for some time, as it always encourages the growth of these perennials very much.

But if perennials considered as a crop are advantageous as a weed, they are much more prejudicial than animals, as it is much more difficult to extirpate their roots, and as they require a great deal of nourishment, which they draw to themselves, to the prejudice of the crop.

* The justness of this distinction every person but little acquainted with agriculture must allow.

4. *Of Manures.*

Manures act upon the ground by supplying a quantity of mucilage, and sometimes by dissolving the mucilage already in the soil, and thus making the water more diffusible. I shall take notice of these separately.

1. *Of Manures that act as Solvents.*

These solvents are principally of a saline nature; and of saline substances, those that are usually employed for this purpose, are either alkaline or neutral; as acids have never been used as a manure.

With regard to saline manures in general, we may observe that they are employed wholly as solvents, and not as furnishing the food to plants; the proof of which is, that if they are dissolved in pure water, and plants raised in that, they either produce no effects at all upon the plants, or poison them* entirely.

These manures, therefore, prove useful to vegetation only by acting upon the soil, and dissolving its gluten, by which it is rendered more pervious to moisture and the roots of plants.

Ashes of burnt vegetables are the first saline substance used as a manure that I shall take notice of.—This acts in consequence of an alkaline salt contained in them, and are a very useful manure where they can be had in any quantity, but it is in very few places that they can be got.

Soot† is the next saline manure I shall mention. This should be spread thinly over the ground in the spring, that it may have an opportunity to be washed into the ground with the rains; for if the weather is dry it produces little effect, as it is apt to be evaporated by the heat and winds. If this is laid on thick, it is apt to dissolve the roots and stalks of the plants entirely, if it comes much rain. I once saw upwards of an hundred bushels laid upon an acre, which produced an extraordinary crop; but the season was dry, and it is difficult to say but it might have produced very bad effects, if it had been rainy.

Common salt is the only neutral that has been used as a manure, but this, as well as all the other saline manures, ought never to be laid on any soil but such as are richly impregnated with mucilages; when it is laid upon such a soil it will produce very great effects, but it does rather harm to a barren soil. As to the quantity of common salt to be used, I think any thing below two hundred weight to the acre will have hardly any effect, and upon a rich soil, it may be safely increased to four bolls. This, if laid on in great quantities, kills the vegetables on the soil for a year or two, but afterwards the ground produces great crops. For a more particular account of this substance as a manure I refer you to the Philosophical Transactions, No. where it is treated of very particularly.

* Saline manures may be with more justice considered as acting by stimulating, than as aiding by increasing the solvent power of water, which is indeed a doubtful fact.

† *Soot* is a sublimate, consisting principally of carbon in a most subtile powdery state, and ammoniac or volatile alkali. Whether the carbon can be observed, is an undecided question; but the volatile alkali operates as a stimulant, and it may even prove nutritious; for it consists of hydrogen and azote.

Nitre has likewise been very much talked of by some authors, as being the food of plants.—It differs, however, in no respect, from the other salts, when tried for the purposes of vegetation. If it is dissolved in water, and any plant made to grow in it, like other salts, it either kills it or produces no manner of effect, and agrees, in every other respect, with other saline manures.*

Much has been said, and wrote, about the influence of saline substances, especially nitre when used for *steeping* before sowing. But, I imagine, that if steeping had produced all the effects that has been ascribed to it, it would have been much more used by practical farmers than at present it is. For although *steeping* has been a long time practised, yet it has never been generally used to any grain except wheat; and I find that practical farmers differ much from one another about what is the most proper thing to use as this steep, some using one thing and some another; some using common water, and even some very eminent farmers using nothing at all. From all which I apprehend, that almost all these wonderful effects sometimes ascribed to this are only imaginary. It is indeed probable, that steeping grain in water some time, immediately before it is sown, may be of service, by moistening the grain and making it vegetate more equally, and by giving an opportunity of washing the smult from it, and separating some light grains; but this I imagine is the utmost to which its influence extends. Some of the saline brines, by being more buoyant, may answer this purpose more effectually; and it is possible that the small quantity of salt which may adhere to the grain may produce some effect on the ground; but this effect may be very small. Considering the small quantity thus used, it can produce no effect upon the seed, further than acting as a poison, as has been sufficiently illustrated already.

Quicklime ought also to be ranked among this class of manures. This is much more generally used than any of those I have hitherto mentioned, and the manner in which it operates perhaps more difficult to explain than any of them. If we should attempt to explain its operations by considering it as an earth, it would appear at first sight absurd, and nobody has ever made the attempt in this way; it must then act as being soluble in acids or water, or perhaps in both ways. Probably its effects at first are chiefly owing to its solubility in water, and considered in this light, it acts like all other saline substances, most powerfully on those soils that are most richly impregnated with mucilage, which it dissolves and renders more fluid.†

The effects of quicklime on mucilaginous bodies is prettily illustrated, by an easy experiment with isinglass; if this is dissolved in water, it suffers it to evaporate very quickly till it comes to a certain consistence, after which it evaporates more slowly

* In a certain dose, as a stimulating manure, it may do service.

† I know not how far this explanation of the mode of operation of lime may be satisfactory to others, but I confess it appears to me embarrassed, and inconsistent with fact and principle, while, on the contrary, a very simple and clear manner of its operation might have been offered. Quicklime, like salts and earths, perhaps is not itself nutritive; but, like alkaline salt, stimulates the plant—it thereby accelerates its growth, applied in due quantity and at a certain period of vegetation. If it be applied in larger quantity it kills animals in the soil, and also small vegetables; and from the destroyed and decayed animals and vegetables a soil is rendered fertile, because impregnated with mucilage.—The superabundant lime to what is necessary to kill vegetables, does not prove hurtful; because it becomes mild calcareous earth, by attracting carbonic acid from the atmosphere. A most satisfactory and pleasing example of the effect of lime is to be found at Buxton; where almost all the grass land near the town has been produced by throwing lime upon the heath, from the decayed state of which *spontaneously* arose excellent grasses, but particularly white clover.

than before; but if it is dissolved with lime-water it is much longer in evaporating to dryness than the other; which shows that the lime assists the mucilage to detain the water much longer than it would otherwise have done.

This substance may be applied in much larger quantities than any other saline manure, as there is little danger of laying it too thick upon a good soil; for we always see that where the heaps of lime have been laid, and consequently where it is thickest, it produces no other effect but that of making the crop there more luxuriant.* I knew once an instance where there had been a heap of lime mixed with earth, in the end of a field, and, by the negligence of servants when driving it out, some of it was left lying in a heap, so that the lime in that place would have been at least three or four inches thick; the effect of which was, that for several years the corn on this spot grew always so luxuriant as to fall over, and rot before it was ripe; at length, however, it became more weak, so as to allow the grain to ripen, but it always continued richer than the other parts of the field. I therefore imagine, that we oftener err by laying it too thin than too thick. There is only one case where we can err by laying it too thick, and that is where the mucilage is already very thin, and the soil loose. If lime was laid upon a soil in this condition it would render it still thinner, so as to allow it to be washed out of the soil altogether; even if the mucilage in a stiff soil is rendered too thin, it is apt to be absorbed by the roots of plants, and thus wasted; but it is a general rule, that the richer a soil is, the greater quantity of lime may be applied to it with safety.

If lime acts as a saline substance, soluble in water, the more recent it is used it will be the better; and therefore it must be a wrong practice to let it lie long exposed to the air before it be put into the ground; and, in order to cause it to produce its full effects, it ought to be ploughed in as soon as spread. Hence then, I imagine, the best way of using quicklime, is to take it immediately after it is burnt, and spread it on the ground in a dry, powdery form; but some people imagine it is better to have it a little moistened before it is spread. This manure is not near so apt to sink into the soil as has been usually imagined.

As to its duration. As a quicklime, soluble in water, it cannot be very great; for it will not be long before its air will be restored, and it will then be converted into the state of a calcareous earth, after which it will act in a different manner. Its duration as a quicklime, however, will be in some measure determined by the different management of the soil; for frequent croppings do wear it out.

It will likewise be more or less durable, according to the different natures of the lime itself. It is a general rule, that that lime which is soonest slaked, if left to the air, will usually have the shortest duration; and those which have the shortest duration, have always the greatest effects while they last.

This finishes what I had to say of saline substances. I now proceed to consider those of the second class.†

* This is an error. There are many instances of soils rendered barren, for some time, by over-dosing it with lime.

† The illustrious Professor has not mentioned recent bone, and bone ashes, in his list of earthy and saline manures; but has mentioned them among the mucilaginous. Bone ashes are bone freed from its oil and mucilage by burning, which is then merely phosphoric acid, united to lime or phosfate of lime. Bone, in the former state, may be considered as both *nutritive* and *stimulating*; and in the latter state of ashes, it is merely stimulating. Of all manures hitherto employed, bone is perhaps the most permanent. What is here said of bone in its recent and burnt state, applies to horns, hoofs, wool, feathers, and air; like bone, they consist of phosfate of lime, and animal oil and mucilage. hair

Mucilaginous Manures.

We have already shown that mucilage is one of the most necessary ingredients in a perfect soil; but as this is apt to be washed from the soil by rains, or evaporated from the earth by the sun, or converted into a saline substance by the fermentation which in many cases it produces, being allowed to go too far—as in these, and other manners, it is apt to be destroyed, the soil stands often in need of a new supply. I shall now mention the several methods which have been used for getting a supply of this mucilage.

And here I cannot help taking notice, that this theory which I have been advancing seems to be entirely confirmed by practice.—Or at least, whether the theory be right or not, it can do no harm, as it leads us to the use of all those manures which have been acknowledged useful among all the knowing farmers throughout the world. I am indeed of opinion, that *no manures are necessary as a nourishment to plants*; but still these manures are useful, as they supply a mucilaginous substance, which we have formerly shown to be so necessary to a perfect soil. And whether *mucilage acts as affording a proper nourishment, or not,* is only a matter of curiosity and speculation. The practice is the same, whichever way that question is to be decided.*

1. All *recent animal substances* afford this mucilaginous substance; as *blood, serum,* and other animal substances, in a recent state.

All the *solid parts* of animals are likewise useful in this respect; but their effects are more or less obvious, as they are more or less soluble in water; and therefore different kinds require somewhat different management.

Wool is one of these which cannot be rightly applied in its native state, and can be much better applied after it has been wrought into *cloth*, the *cuttings* and parings of which are extremely useful for this purpose. From my own experience, I find that this measure has more lasting effects than is usually ascribed to it, as it produces very sensible effects five or six years after it is used. As to the quantity, one hundred stones to an acre is a very good proportion.—If it is laid on thicker, it is apt to make the ground too luxuriant. This manure does not produce its greatest effects at first, the crop being better the second or third year after it is applied.

Hair of animals has likewise been used for the same purpose, and with much the same effect.

Horns of every kind are an useful manure, when cut into small enough parts; but in their natural state they produce little effect. When rightly applied, they are an extremely rich manure. The proportion necessary to be employed varies according to the bigness of the chips; fewer being necessary when small than large; but the effect of the larger are longer felt. If the shavings are neither very large nor very small, about sixty stones to an acre is a good proportion. If more is used, the grain is apt to be too luxurious, and too long in ripening; and when either horns or rags are too thick, the grain is very apt to be hurt by mildew.

* The truly candid and philosophical mind of *Cullen* is displayed in this paragraph. His doctrine, as far as relates to practice, it is believed, will be found perfectly just; and if subsequent observations have shewn that the theoretical part is less probable than formerly, still it is a proof of Dr. Cullen's sagacity, that he perceived that mucilage, however it may operate, is absolutely necessary to the formation of a fertile soil.

The bones of animals have likewise some effect; but as they are very solid, the air has but very little effect upon them, and consequently their operations are slow. But by digesting them for some time, they have immediate effects.

These are some of the singular methods of recruiting the mucilaginous substances, which can only take place in some particular circumstances. But the most common and general resource, is 2. The *putrid parts* of animals, or vegetables; as dung, which acts in a double capacity, both as a mucilage and saline manure, and therefore may be the most universally useful of any manure whatever.

The dung of different animals is not alike valuable in all circumstances, and much has been said of the different effects of these. I shall endeavour to inquire whether there are any rules of judging of the effects of these from reasoning, and point out some of the circumstances which may produce a change in the nature of the dung.

The first of these is, from the heat of the animal in its ordinary state; for always the greater the heat of the animal is, other circumstances being alike, the putrefaction will be carried on the farther in a short time.—Let us, therefore, in judging of the nature of different dungs, never forget this. And to assist in this inquiry, it may be necessary to observe, that the animal heat is smallest in man, next to that in quadrupeds; and fowls have a greater degree of heat than any of these. Therefore the dung of fowls ought to be more exciting than that of any other animals.

Secondly, The food the animal lives upon will produce an effect upon their dung; for that of those who live upon animal food will be more putrefied than if they fed upon vegetables. In the same animal, living upon vegetable food, there will be a difference in the dung, produced from the more dry or succulent plants. Hence, likewise, there must be a difference between the dung produced from green or dry food, and more especially if the latter is of a rich nature, as grain. All which considerations are necessary to be attended to, in order to form a judgment of the nature of the dung of different animals. The cow chooses the most succulent kind of vegetables, while the horse requires a warmer kind, and sheep and goats require still a drier food than any of them. And hence is probably the reason that the dung of cows is usually less esteemed than of horses, while that of sheep is preferred to both; and the dung of pigeons will be warmer than any of these, both on account of the greater heat of their body, and of the nature of the aliment upon which they feed, that being always the more dry and nourishing parts of vegetables, grain and other seeds.

Thirdly, The exercise of the animal may perhaps have some effect upon the dung; for as the heat is increased by motion, the putrefaction will of consequence be more accelerated by it.

Fourthly, The length of guts ought, for the same reason, to have the same effect; for the aliment being the longer retained in the body, will give occasion to a greater degree of putrefaction to take place. All these circumstances will produce an effect upon the nature of the dung; and whatever gives occasion to promote putrefaction (according to the received meaning of that word), of a better nature. It is to be observed, that the further the putrefaction is carried, or, in other words, the hotter the dung is, the more it approaches to the nature of a saline manure; and *vice versa.**

* This reasoning is ingenious, but not satisfactory; nor is it consistent with the Professor's own proposition, that the only real nutritious matter is rain water. But rain water is considered purely as a solution of putrefied matter. There is good reason, and many facts, to induce us to believe that putrefaction is no way necessary to the nutritive power of animal and vegetable matters, but in so far as it diminishes their cohesion or de-

This consideration ought therefore to be attended to in the application of manures; those of a warm and exciting nature being more proper for lands already enriched with other manures, and the cooler mucilaginous kinds being more proper for barren poor soils. But as we have much oftener occasion for the mucilaginous than saline manures, we ought to be at all proper pains to increase the quantity of that; which leads me to another source of that manure.

3. A most copious supply of the proper mucilaginous manure may be obtained from vegetables, as all vegetables are, by putrefaction, reduced to a mucilaginous substance; but as the more solid parts of vegetables, like those of animals, are but very slowly dissolved, these will have but a small effect; wherefore those of a more lax and tender nature are usually preferred for this purpose.

These differ from animal dung in this respect; that whereas animal dung always affords the greatest quantity of mucilage when in its recent state, vegetables afford but a very small proportion, until they have undergone a degree of fermentation. And this is the reason why recent vegetable manures, as a crop of clover or pease, ploughed down, or dry vegetables, as straw, &c. often disappoint us of our expectation; for these, by being in such small quantities together, cannot be made to undergo a perfect kind of fermentation; and as the mucilage will thus be formed slowly, and in small quantity, it will be apt to be washed from the soil as fast as it is formed, it will produce very little effect.

These are the reasons why recent and dry vegetables are but weak and ineffectual manures; wherefore they ought always to be previously fermented. The most proper manner of effecting which is, by mixing them with animal dung, and allowing them to remain in a heap till it has undergone the degree of putrefaction necessary. By this means the animal dung, which is already putrid, acts as a ferment to the vegetables mixed with it; and as this of itself has too little mucilage, the vegetables mixed with it supply that defect, and in this manner the faults of both are corrected, and a most perfect manure obtained.

This is the composition of our common dunghills. And as a great deal depends upon the proper management of these, so as to produce the desired effects, I think it an article of such importance as to deserve our very particular examination. I shall therefore lay down some rules for the proper management of dunghills.

1. As dunghills are always composed of animal dung mixed with vegetable substances, some degree of fermentation is necessary to bring it to a proper state for a manure; and as no fermentation can be carried on without moisture, it is necessary that the situation of it be such as to prevent it from being too dry; but it is likewise necessary to preserve it from too much moisture, not only because the putrefactive fermentation takes place much more readily when there is not a great deal of moisture than otherwise, but also because the mucilage by this fermentation is soluble in water, and therefore may be readily carried away by the superfluous moisture, if it is permitted to run from it.

Hence, therefore, the dunghill ought to be so situated as to retain some moisture, but defended from all extraneous moisture, except what rain may fall upon its sur-

stroys their texture, and thereby renders them fitter for absorption; and as there is a considerable waste in gazes, and ammoniacal and nitrous salt, by the putrefaction, it is of importance not to allow the putrefaction to take place at all, where it is not required to break the texture; and where it is necessary on this account care must be taken not to extend it too far.

face; for if it is defended from water falling from houses, or running from higher grounds, it will never be too moist, except perhaps at very great falls of rain; to prevent which inconvenience, if at any time it should happen, a conduit ought to be contrived to draw it off at pleasure, which should be conducted into a proper place where some loose earth is prepared for absorbing it, which, after a sufficient time, will become richly impregnated, and may be advantageously employed as a manure.*

The time that dung ought to be kept in the dunghill likewise deserves our serious consideration when treating on this subject; for although we are often confined so as to be obliged to lay on our dung at certain seasons, so that we must keep it till, or use it at that period, whether it be in the most proper condition or not, yet it will nevertheless be useful to know at what time it can be employed with greatest advantage, that we may order our operations in such a manner as to seize that favourable period as often as in our power.

The time that dung ought to be kept will vary, according to its quality; the different purposes for which it is required; and the management that the dunghill gets. If there is little vegetable substance in proportion to the animal dung, it will require shorter time to come to its perfection; and this ought ever to be remembered in the future considerations. If dung is wanted to act as an exciting manure, it ought to be kept longer than if it is intended to act as a mucilaginous; for after the mucilage is formed, the putrefaction still goes on, and a saline substance is produced which communicates to it the quality of an exciting manure. But it is to be observed, that as the saline substance thus formed is of an extremely volatile nature, and is therefore exhaled by the sun almost as soon as formed, if it is allowed to remain long, the whole will be exhausted, and nothing but an inert earth remain. To prevent which as much as possible, any dung that is wanted to act in this manner, ought to be covered from the sun and wind with the greatest care; but so great is the volatility of this body, that no care or pains can prevent its evaporation; and if it is allowed to come to that state, it always loses something, insomuch that it never goes so far as if sooner used; for which reason, I imagine, the most proper time for laying it upon the ground is when the mucilage is all thoroughly formed, and no more.

This may be pretty well known by the appearance that it puts on at that time, which is black, moist, and resembling an oily substance. If it is allowed to proceed farther, it loses that bright black colour, and becomes more dusky, dry, and crumbly than before. If it is not come to that point, the vegetables will be still in some measure fresh in appearance, and retain something of their natural colour, and the animal dung will have a reddish appearance.

Dung may be reduced to this proper mucilaginous state, more or less quickly, according to the management of the dunghill. For as the putrefaction advances the faster, the more closely it is pressed together. A greater or less degree of pressure will cause it to come quicker or more slowly to that state to which it is required.

This is a peculiarity which may be employed with the greatest advantage in the management of dunghills; for as these are made up gradually as the cattle make the dung, without taking advantage of this circumstance, it must always happen, that when the dung is led out, one part of it is too much while another is too little fermented. But if care is taken to tread the dung that is first made on lightly, and to avoid treading upon it as much as possible, while that which is later made is more

* Such earth will be a most excellent stimulating manure, being impregnated with ammoniacal salts, nitrous salts, and phosphoric salt.

and more firmly pressed, the fermentation will be more equally conducted through the whole, so that at leading out it will be much more nearly of the same nature.

Composts of earth and dung, &c. have been so much praised by some, that it would be unpardonable not at least to mention them; and as this is the proper place for it, I shall add a few words with regard to them.

It has been alleged, that by mixing dung with earth alone, the quantity would be much augmented, and the quality not diminished, or even impaired; but I can by no means agree with any of these positions. It is indeed possible, that by mixing earth with dung, it may in some cases incorporate more readily with the soil; but from any proofs that I have had, it appears that the same number of cartloads of dung are necessary to an acre the one way as the other; and therefore I imagine the benefit does by no means compensate for the expence of making it, unless when the earth that is mixed with it is of an extremely fertile nature; as scourings of ditches, bottoms of ponds, or other rich earth, which of itself would be an useful manure without the dung; in which cases it may, or may not, be mixed with the dung, at the pleasure of the possessor. But if they should be at any time mixed, I am inclined to believe that nothing is gained by frequent turning of them, but rather, on the contrary, that it sustains a loss.

Lime is sometimes used in these composts, and so properly, that I imagine it should never be omitted, especially if it is to be kept long; because, by its antiseptic quality, it will retard the fermentation.

When dung is thus obtained, it may be applied to the ground, in two ways, either by spreading it on the surface of the ground, and allowing it to be washed into the soil, or by ploughing it into the soil as soon as it is spread. If it is employed in the first manner, it ought to be spread out in the spring of the year, before the sun has so much power as to exhale its virtues too quickly, and while there is no great probability of heavy continued rains to wash it from the soil. The older dungs are usually preferred for this purpose. But the most advantageous method of applying dung is, by ploughing it into a well wrought soil (while yet in its mucilaginous state) with a slight furrow; for if it is put in deep, it is apt to be washed through the soil by the rains.

These that I have mentioned are the principal, though not the only sources of the mucilaginous matter. The *soil itself* may be termed *a matrix for this useful substance*, producing more or less according to different circumstances. Thus the worms, and other reptiles, which die in the earth, afford a quantity of rich animal mucilage. But this is inconsiderable, in comparison of that produced by the rotting of vegetable roots which have been produced in the soil, which is probably one chief reason of the little difficulty of preserving a soil in good order after it has once been brought into that state, in comparison of another soil that has not been originally so rich; for the great abundance of roots always produced in the one must supply a great deal of mucilage when reduced by fermentation to that state. But as vegetable substances of themselves putrefy extremely slowly, and therefore in this instance are apt to be washed away as soon as formed, in this slow manner, it is not only necessary to put the earth in the situation best fitted for promoting this fermentation, by keeping it free from stagnant, or too great a quantity of water, and at the same time properly moist, &c. but also to add such substances as promote the fermentation; the most powerful of which is, the adding a sufficient quantity of animal dung, which, acting as a ferment, greatly assists the formation of this mucilage.

Besides animal manures, we may employ others to produce this effect. All acids are antiseptic; and therefore, when they are present, retard the formation of this mucilage. Acids* are copiously present in every soil; and hence it is evident, that whatever destroys them must promote the fermentation. Hence, therefore, calcareous earths, which absorb the acid and convert it to a neutral state, will promote the fermentation in the soil, and therefore be useful manures. And this, I imagine, is the effect of marls, and all such manures as contain a calcareous earth.

The manner in which marls operate, seems to confirm this opinion; for as the quantity of acid generated in any soil cannot be very great, a small quantity of the marl must suffice to absorb the whole, and the rest of the calcareous earth remaining in the soil will be ready to act upon the acid afterwards, as soon as formed. And hence the reason of the very lasting effects of this manure.

I have just one other source of mucilaginous manures to mention; which is, *rain water*; which is perhaps of as great and extensive influence as any that I have mentioned.

All water, if allowed to remain stagnant for any time, is disposed to putrefy;† and when it has undergone a putrefaction, it always deposites a mucilaginous substance at the bottom of the vessel in which it has been kept. Now the water which is deposited in a soil is determined more immediately to this kind of fermentation than by any other management; because of its being mixed with a quantity of animal and vegetable substances, and assisted by the heat of the sun, and fermentation occasioned by these; besides which, as a quantity of mucilage is always deposited by the evaporation of water, however quickly performed, the soil receives an addition by the alternate moistening and drying to which it is perpetually subjected.—And this, I imagine, is one great assistance to fallowing. Dews are useful in the same way, by reason of their containing more mucilage, and of their greater tendency to putrescency, are much more rich and useful than rain water.

Thus, gentlemen, I have mentioned a few of the most general rules relating to vegetation and agriculture that have occurred to me. I have been but very short upon each of these; and perhaps have omitted something of importance. But to have entered into a particular discussion of each of these would have filled volumes, instead of being contained within the compass of an essay.

I am contented with having traced the outlines, and leave every one to fill up the rest in the best manner he can. And if, after trial, any of you shall find the above theory in any respect contrary to practice, it will do me a singular pleasure to be acquainted with it, that I may correct my errors. Truth, and the advancement of an art so useful to mankind, is my sole object; and to attain this, I hope, I shall be ever ready to sacrifice any theory, however dear it may formerly have been held.

* I know not what acids, in a free state, are in every or even in any soils.

† Water is incorruptible. Water only appears to putrefy, from the animal or vegetable matter contained in it; and there is no such matter in pure rain or snow water, or distilled water. Therefore they would keep sweet for ever.

ABSTRACT of Dr. CULLEN's Lectures on Agriculture.

LECTURE I.

1. All plants derive their nourishment wholly, or chiefly, from the soil. We must then inquire,

2. What is the nourishment of plants? where a previous question occurs.

3. Whether or not all plants have one common nourishment? That they have, I am strongly inclined to believe; or at least that the diversity is very inconsiderable.

α. We observe not different contents in different soils; their contents are used in different proportions, but of no different qualities. In the lixiviation of different soils, scarce any sensible difference of quality is to be found.

β. The soil of a garden carried into the green-house will raise plants of all climates.

γ. It appears from some experiments, that the roots of plants have an elective attraction for some sorts of nourishment, but cannot reject any. Grafting and inoculation, a further evidence.

δ. We see, however, that different plants affect different soils. Spurrey grows plentifully in sand, and used in some places to cover their sand-banks, where rushes could not subsist. It is the different texture of the soil, and a different proportion of nourishment, not any different quality, that makes plants thus show an attachment to different soils.

To ascertain this point supersedes all inquiries into the peculiar nutriment of peculiar plants.

4. With respect to the second question. We take the nourishment of plants to be rain water alone.

α. All seeds may be made to graminate in water, to such a degree as to produce their peculiar juices.

β. Du Hamel kept an oak growing in water eight years, and might be longer continued did not the water at length disease the roots. This also is confirmed by Mr. Boyle and Van Helmont's experiments.

γ. Mr. Bonnet, of Geneva, found, that plants did not grow so successfully when their roots were floating in water, as when only moistened with it by the intervention of some other body. With as a soil, in flower-pots, he raised oats, wheat, &c. to as great perfection as in the earth. *Qu.* Will not the arena quartoza answer this purpose?

The earth then is only the filter; rain the common nutriment.

δ. *Objection.* That the earth requires to be renewed with manures. *Ans.* We have instances of some soils affording constant annual crops, for one hundred years, without manure, supplied with nothing but rain.

ε. Some manures last from thirty to fifty years. These are of themselves unfit for vegetation; not soluble in water, at least not till some other substance render them so: and no observation shews that even this will then nourish plants.

ζ. Tull's scheme is to keep up a certain texture in the soil, that the earth by being thus pulverized becomes more fit to enter plants, is false. But the alteration of its texture renders it better adapted for the reception of roots.

7. If we examine the quantity of nourishment in a soil, it is inconsiderable.

Does this alimentary matter then consist in elementary water? It does not. But in an impregnation of rain water. What this impregnation is, we need not inquire. The only matter, or chief matter in rain water, is animal or vegetable matter dissolved. This we cannot separate by any distillation, but are assured that it is still in the water from its putrefaction.

LECTURE II.

Roots.

1. Vegetation, *cæteris paribus*, is always in proporrion to the quantity of roots. The multiplication of roots is therefore the chief object of husbandry.

2. All roots depend for nourishment on their fibrous parts. Hitherto it has been generally supposed, that the roots absorbed nutriment by their whole surface; but from some late observations it appears, that they absorb the moisture of the earth mostly, if not wholly, at their extremities. Bonnet, when he immersed roots into tinged liquors, found that they did not enter by the surface, but only by the extremities.

3. Du Hamel's experiments led him to conclude the same; and farther, that the fibre cut through did not absorb such a quantity as the natural apex. He further found, that the trunks and parts above ground grew by equable extension, but that the roots were prolonged only at their extremity. If any fibre was cut through, it grew no longer in length.

4. This absorbing part at the extremity consists not in a point, but has some small length. If cut an inch from the apex, the fibre will no longer lengthen; but will, if cut but a line; and so far Bonnet found the extremity of the fibre tinged.

5. Agreeable to all this, plants, having their roots cut, languish till they get new lateral shoots.

6. Roots affect moisture, and cannot be produced without it. If placed in a moist stratum betwixt two dry ones, they will spread only in the moist one.

7. The formation of roots depends on a proper degree of moisture and penetrability in the soil: but this in different degrees in different plants. Some thrive in a dry and adhesive soil, others in water.

8. Water does not produce a root with so many absorbing extremities as earth.

9. Branches set in earth produce roots, and roots in air branches that produce leaves.

10. Resisting soils occasion roots to spring laterally; light soils longitudinally. But a middle degree of penetrability will give the greatest degree of absorbing mouths. To procure this middle temperature, soils are the chief object of husbandry.

But before we proceed to this, we may add the following observations on roots.

Obs. 1. That the cutting of roots promotes vegetation by augmenting the lateral shoots. This is one of the chief advantages of the horse-hoeing husbandry, in which the fibres are equally broke.

2. There is a constant correspondence betwixt the roots below and the stems and leaves above, for they grow always in proportion. When the vegetation in the roots is stopt, the vegetation in the stems and leaves is of course interrupted.

3. The stoling, or tillering, of plants, is somehow connected with the progress of vegetation in the roots. It is observed, that corns tiller less in open soils than in

stiff, because the roots run longitudinally, not being checked. By cutting away the leaves, we check the progress of the root, and promote the tillering. Thus, in England, they eat down their wheat with sheep, and we cut our luxuriant crops with a sickle.

4. If potatoes be entirely cut over when they rise, it causes a more vigorous push of roots; but it is only of fibres. If repeated, a prodigious root of fibres is produced, but no tubera.

5. Roots entirely fibrous thrive best in a moderately stiff soil, but bulbous roots require a soil more open.

6. Culmiferous plants have three sets of fibres. The first set is formed in the radicle; the second set is formed above this, at a knot, on the plumula; the third on a knot on the plumula, above the second.—This is the discovery of Bonnet. Upon the due formation of these three knots, and sets of fibres, I judge the tillering of frumentaceous plants does entirely depend; that if these knots are imperfectly formed, the plant imperfectly tillers.

7. These three knots are termed, by Bonnet, the infancy, adolescence, and maturity of the plant.

8. At the two uppermost knots the tillering is formed.

LECTURE III.

1. Water is necessary to roots, but not in its fluid state; for this produces a faulty formation of roots. Some plants indeed grow in very dry soils; but they are such as absorb most by their leaves. In indurated soils, and substances, plants can never vegetate; these being impervious to their roots. A certain degree of moisture and penetrability is therefore necessary in a soil. To attain these two grand pre-requisites, we must know what are the ingredients in the soil that is most proper for vegetation.

2. These are clay, sand, and mucilage.

Clay.

3. The substance that appears most apt to absorb and retain water, is clay. It is therefore to be considered as the basis of soils. It is the only earth that can absorb water into its substance. It can absorb a certain and large quantity of water, so as to destroy its fluidity. But if a larger quantity be added, its fluidity is discerned by the viscidity of the clay. So intimate is the connection betwixt clay and moisture, that the latter can by no degrees of fire, nor by any means, be entirely separated from it.

Sand.

Sand again can absorb no moisture. Water enters only the pores, amongst its grains, not its substance. Mixed, however, with clay it renders it more pervious to moisture, keeping it divided. Several writers on agriculture have rested in this mixture of sand and clay as sufficient to form the best of soils, a loam. But sand and clay, when dried, hardens to a greater degree than clay by itself, unless the sand be in a very large proportion. Where there is much sand in a soil, the rain washes down the clay to the bottom. A mixture of clay and sand alone can never therefore make a proper soil. Pure clay is very different from that which is in soils; the former is always destitute, the latter is always blended with vegetating matter. When clay is capable of forming a good soil with sand, it has different properties from pure

clay; yet pure clay, when exposed to the air and rain, requires the same vegetating matter. Pure clay cannot resist the vicissitudes of dryness and moisture so well as the clay in a soil. If both are drenched with so much water that some of it appears fluid, the water will evaporate, to a certain quantity, more quickly from the last. But when both are apparently dry, it will be found to contain more moisture than the first.

Mucilage.

5. Mucilaginous substances, whether animal or vegetable, can unite with a considerable quantity of water, so as to entangle it and destroy its fluidity. When they are diffused in water, they will allow part of it to be readily evaporated; but when they turn viscid, they very powerfully resist evaporation. This is the property we want in our clay; that it can unite with much water, destroy its fluidity, and retain it powerfully. This property these mucilaginous substances afford; and I have found, that when mixed with clay in a small proportion, it will actually retain much more moisture than it would otherwise do.

1. All animal and vegetable substances turn mucilaginous by putrefaction. This is the mucilage which, with clay of sand, is required to form a perfect soil.

2. Pure clay is only changed to soil near the surface of the earth, where it receives the admixture of animal and vegetable substances.

LECTURE IV.

1. The most perfect soil is what contains most water without being in a fluid form.

2. The viscidity of clay is owing to what water is fluid in its pores, not to what it properly absorbs.

3. It is owing to the mucilage in soils that they dry without induration.

Diversity of Soils.

1. Soils are different according to the different proportions of clay, sand, and mucilage. But, besides these, there are some other ingredients.

2. Vegetable fibres abound in every soil. Moss consists of vegetable substances alone. Sponges absorb moisture in consequence of their cellular texture.—So it is in moss. But in both the water is in a fluid form. Hence nothing but aquatics can thrive in pure moss.

3. A quantity of calcareous earth is readily soluble in all acids, which clay is not. It is in some degree present in all soils; as all animal and vegetable substance is reduced by putrefaction to a calcareous earth.

A selenites, a mica, or fine talc. This we will find in almost every soil. It is the above calcareous earth formed into a selenites, by the vitriolic acid, which abounds in the air. Its properties in the soil I cannot well determine. The quantity of it dissolvable in water is inconsiderable. I have been often surprised at the vast quantity of it in some soils. In this case it may serve as sand.

These are not necessary, but very constantly to be found in all soils. Beside these, there are some other less considerable, or less frequent, ingredients.

1. Saline matters we sometimes, but rarely, find in soils, except such as are the product of putrefaction.

2. Oleaginous substances, though not always visible, are diffused almost wherever there is water; but never in soils are they to be found, except as proceeding from putrefaction.

4. Iron of the metals is alone obvious to us in a soil. It enters the composition of every clay. It is iron I judge that gives viscidity to clay; but am uncertain in what form it is when it has this effect. Vitriol appears unfit for this purpose; and ochre seems rather to give friability.

Division of Soils.

1. Heavy soils are such as contain much water and give much resistance to the roots of plants. Clay produces both these effects. We are to distinguish, however, the stiff from the strong soil. The first is called so from its resistance to the roots; the other from its fatness and fertility. Light soils are generally owing to sand, though perhaps to chalk, or the selenites. The naturalists now distinguish betwixt sand and grit. The first, a congeries of crystalline, and somewhat regular bodies; the other, a collection of dark and irregular bodies, that formerly existed in greater masses.

2. Loam is of a middle nature betwixt the two former. In it the proportion of sand is exceeding great; yet I have never seen loam so fertile as some soils with a far greater proportion of clay.

Cæteris paribus, the deep soil is always the driest. Any given quantity of moisture will moisten a small depth more than a greater; so that soils are often dried by being deepened. Stony bottoms afford the driest soils. Clay soils will be more or less wet, as they are more or less impregnated with mucilage.

LECTURE V.

1. Warm and cold soils are the same with dry and wet soils.

2. Subterraneous heat, and the heat of the sun, are the only two sources of heat in soils.

3. The melting of snows is oftener owing to the warm vapour rising up through the earth, than to the air. This is evident from snow melting away on the earth whilst it remains on stones. A strong proof of the subterranean heat.

Examination of Soils.

The friability of a soil may depend on mucilage, sand, or calcareous earth.

1. From this mucilage the fertility of every soil arises. To discover its quantity, the soil must be lixiviated. But here we may be too superficial; for the mucilage in clays is not easily extracted by water, without heat, agitation, and frequent affusions.

2. The proportion of sand is ascertained by elutriation. When the sand subsides, the clay may be poured off; and its proportion, by this means, may also be known.

3. Calcareous earth may be discovered, by heating the above two residuums of sand and clay with acids. With acids the sand is not affected. The vitriolic acid is unfit, as it does not suspend calcareous earth. Concentrated acids especially, if assisted by heat, dissolve some part of the clay. The weaker acids are therefore necessary.

4. Friability is the mark of a good soil. If friable, it increases greatly in bulk, upon division.

5. A black colour does generally, but not always, indicate a fertile soil, for such is moss. Clay in its present state is always white, its other colours arise from impregnation. The various colours of soil do usually depend on sand or clay. Pure sand is white, when red or yellow, it is owing to a metalline mixture. Clay is blue,* yellow, and red, the two last derive their colour from iron, and are therefore the most viscid. The first sometimes calcines to whiteness, and so has no iron, its colour arising from some other cause, and from one that is yet unknown.

6. The native plants do likewise discover the constitution of a soil.

In what manner a soil may deviate from fertility, and how recovered.

1. The most perfect soil, if allowed to rest, its clay will concrete, so as to render it impervious to water and the roots of plants. This may be obviated by mechanical division, by heat and cold, by the roots of plants, and the solution of its mucilage.

2. Mechanical division, when most perfect, is but rude and gross. No ploughing of use but when the soil is so dry as to fall to powder. If clay be pasted with water it becomes impervious to moisture, which is effectually done by wet ploughing. The same is caused by the treading of cattle on wet soils.

3. Heat and cold alternately do powerfully pulverize; these, with mechanical division, render the practice of fallowing so valuable. Hence, the good effects of frost on a soil. When frost penetrates so far as to form masses of ice at a great depth, the event of the subterraneous vapours in spring may be prevented, and consequently an early vegetation. Therefore snow with frost is beneficial, as it hinders its descent.

4. Roots are constantly making a progress through the earth, and so always inducing a minute division of the soil. Different, however, at the different seasons of vegetation; greatest when the stems and leaves are luxuriously pushed; but once the fruit appears, the vegetation in stems, leaves, and roots, from that period declines. The growth of the roots being now at an end, they rather favour than prevent the concretion of the soil.

LECTURE VI.

Effects of Roots.

1. Roots not only receive but also communicate moisture to a soil. The moisture they absorb by their leaves seems to return downwards to their roots; at least what rises in the day-time from the roots, subsides in the night, with some increase from the leaves. This evident from experiment.

2. If you transplant a root from a moist to a dry sandy soil, it will communicate moisture to the soil around it, an evidence that some moisture is perspired from the roots; this, however, only happens before the fructification appears.

3. Before the cerealia come to the ear the soil is friable and moist as when the seed was sown, and were they then to be cut down it would not have suffered the least disadvantage, but the contrary; whereas when the ear is produced the leaves wither, and the soil dries and concretes.

4. The legumina again push their leaves and roots after the fructification appears. The cerealia are therefore impoverishing, the legumina meliorating crops. Hence

* The Bishop of Llandaff did me the honour of putting into my hands lately a blue clay, apparently containing oxide of copper; but which, on examination, I found to contain oxide of iron.

the beneficial practice of using these alternately. I knew an instance in a soil that required manure every three years, kept fruitful for twenty four years simply by this alternation.

5. Turnip, carrot, and parsnip crops being used before they seed, are consequently meliorating.

6. Whether or not potatoes are a meliorating crop is disputed. If they are suffered to continue in the ground till they fruit they impoverish, if not, they improve. Their additional bulk after the fruit appears does not compensate for the harm they do the soil by standing after that period. Hence, to raise potatoes early in the season advantageous to the farmer.

7. All perennial plants are meliorating, by the continued vegetation of their roots.

Solution of Mucilage.

1. A fourth way of preventing the concretion of a soil is, by dissolving its mucilage. This is done by manures of the saline kind; acids are always hurtful to vegetation.

2. Alkaline ashes act not as a nourishment to plants, but only as a solvent to the mucilage.

3. Soots afford a volatile alkali and an ammoniacal salt, and act in the same manner with ashes. Both are poisonous if absorbed in great quantity. No difference in different soots.

4. Common salt is also used, but of this and of all other saline manures it is to be observed, that they have no effect on sterile soils, they are exciting not nourishing manures, and presuppose the soil impregnated with mucilage, which it is that province to dissolve.

5. The effects of nitre differ not from those of common salt.

6. Seeds receive no greater advantage by steeping in saline liquors than in common water, which, indeed, may facilitate their germination.

7. Quick lime I rank with saline manures, as it acts upon the same principles, and only so far as it is soluble in water. Nothing in agriculture of which the theory is more doubtful than the operation of quick lime. If we consider it simply as a calcareous earth, it can have no further effects on soils than sand or selenites. If we refer its effects to its solubility in acids, greater quantities of it would be requisite, and its effects more durable; it appears to act, therefore, by means of its parts soluble in water. It is known that lime water is very powerful in attenuating and resolving all mucilaginous matters, and bringing them into such a state as they do not easily concrete again. Isinglass dissolved in lime water concretes not into a jelly, as with common water. Lime water, therefore, renders the mucilage in a soil soluble in water. To have any effect there must be mucilage to work upon, consequently it is unserviceable in exhausted or sterile soils, and by frequent crops tends to throw out those that are rich.

8. There is no danger of the corroding effects of quick lime in a soil; we err in using too small a proportion of it. The more recent the application of lime the better, for if long exposed, it reabsorbs its air, and returns to the state of a calcareous earth. Different quick limes differ in their duration, according as they preserve their texture longer.

LECTURE VII.

a. *Improvement of Soils.*

Soils, we have observed, deviate from fertility by concretion, and the means of correcting this duration we have considered. But soils likewise deteriorate by losing their clay, sand, or mucilage, these essential ingredients of fertility.

B. *Mucilage.*

1. The mucilage is lost by being filtrated with water to too great depth, or by evaporation. Beyond a certain degree of putrefaction it passes from its mucilaginous state, is resolved into a saline substance wholly soluble in water, is no longer fit for giving the texture proper to soils, but becomes an exciting manure. Mixed long in a soil it seems also to degenerate, at least entirely into an inert earth.

2. Tull's system, which places fertilization wholly in pulverizing the earth, renders manures superfluous; yet this is contrary to daily experience. Upon our principles manures are still necessary, not indeed to give nourishment to the plants, but texture to the soil.

3. A soil whose mucilage is impaired, or which entirely wants it, may be easily supplied with it. All animal substance affords it; the viscid fluids in their recent state; animal solids afford it in greater quantity. Woollen rags, 100 stone to the acre, will last for five or six years, will occasion a growth too luxuriant the first year, and are of still more advantage the second.

Dung.

1. Dung both acts as a dissolving manure, and supplies mucilage.

2. The more highly putrefied dung gives the more powerfully dissolving manure.

3. The degree of putrefaction in dung depends upon the degree of heat in the animal; this is least in man, next in quadrupeds, and highest in birds.

4. All dungs hasten to that degree of putrefaction which resolves them into a saline and dissolving, rather than a nourishing manure. To prevent this we mix them with vegetables.

Vegetables.

1. Vegetables are another source of mucilage; when recent they contain so much moisture that they yield little mucilage. Hence, a crop of pease or clover prove but an indifferent manure.

2. In a dry state the putrefaction of vegetables is too slow, in dung alone it is too quick; a mixture of these, which is the matter of our common dunghills, is the most proper manure.

Dunghills.

1. Dunghills should neither be kept too dry nor too wet; a middle state does most favour the necessary putrefaction.

2. It is sufficient, I imagine, that dung be kept one year in the dunghill; if kept two it loses part of its virtue, by approaching too much to the saline state.

3. There is no benefit in mixing dung with earth.

4. Quick lime mixed with dung is an advantage, as it keeps the mucilage in a proper state. By its antiseptic property it prevents the putrefaction from running too far, and the dung from passing into a saline state.

5. Dung, as a saline manure, is poisonous to plants, for we can never catch putrid substances in that degree of putrefaction but some part of them is resolved into the saline state.

6. It is dangerous, therefore, to apply dung to the surface of the earth when plants are springing and apt to imbibe it; it should be laid on in winter, when the succeeding rains may wash it into the ground in a more dilute state.

Acetous Fermentation.

1. The above vegetable substances undergo in a soil the fermentatory process; they pass through the vinous and acetous before they arrive at the putrefactive state. Our business is to hurry them as quickly as possible through the acetous to the putrefactive fermentation; this we do by the addition of animal substances.

2. The acid generated in the acetous state is hurtful to vegetation, and retards the progress of putrefaction; calcareous earths destroy its activity and forward a due putrefaction, by shortening the vinous and acetous fermentation.

3. Such is the effect of marl, a term now understood to be limited to calcareous earths;—the shell marl, which is the purest, is wholly calcareous; the clay marl is this mixed with clay. These absorb the acidity of soils, and determine all vegetable substances to pass more quickly into a putrid mucilaginous state.

4. As the quantity of acid in a soil is not great, the effect of marl will last for many years.

5. Water is a great source, and perhaps the greatest of the mucilage that is in the earth. All water putrefies, and thereby shows that it contains animal or vegetable substance, the only two sources of putrefaction that we know of in nature. Hence it comes to pass that the sediments of all waters are so useful manures.

No. III.

An ESSAY on the FOOD of PLANTS and the RENOVATION of SOILS.

By JOHN INGEN-HOUSZ, Body Physician to their IMPERIAL and ROYAL MAJESTIES, F.R.S. Foreign Honorary Member of the Board of Agriculture, &c. &c.

Best way to find out the true food of organized bodies.

THE surest way to find out the real nourishment of organized bodies seems to be, to inquire what is the substance, without which they inevitably perish, and which alone is sufficient to continue their life. All animals require two ingredients for the continuation of their life; viz. atmospheric air and moist food, derived either from animal or vegetable substances, which food being received in the stomach, or some reservoir destined for that purpose, and being gradually digested and changed into different substances in the different organs, is applied to the whole economy of the animal body. Vegetables being deprived of progressive motion, by which means the most part of animals go in search of food, must find, in the narrow compass of space they occupy, every thing necessary for their subsistence. As they are in contact with two substances only, the earth and the atmospheric air, their nourishment must exist in either of them, or in both. The earth is necessary to the plants, as the only means to fix them stedfastly to the spot, by spreading through it their roots; but as earth contains generally moisture, salts, air, &c. nature has taken advantage from this circumstance, so that the filaments of the roots pump from the soil all that is offered to their suckers, and can be absorbed by them; but as some plants may live and thrive without being in contact with any earth, we ought to take it for granted, that the soil, or what exists in the soil, is not the only food of plants.

Why water is an ingredient necessary for all organized beings.

Water is necessary to all organized beings, as without it no circulation of juices could be carried on; but from this necessity it can only be deduced, that water is a vehicle of the food, and by no means that it is the true nourishment of animals or vegetables—the less so, as it is an incontrovertible fact, that several plants can live without being in contact with water.—Thus the agave, cactus, aloe, cacalia, &c. live in the most dry rocks in the hottest climates, where it does not rain sometimes in the space of several months,

How the most succulent plants can live in the driest rocks.

and where the burning sun pierces all other plants, and even deprives the trees of all their leaves, and, what is extraordinary, the most part of such plants are full of juices. The nocturnal dew cannot give sufficient nourishment to such plants, as all other plants would also maintain themselves with it. But to be certain that those plants do not subsist by dew, we ought to consider only that some plants of that species may be kept alive in the hot-houses, either in pots, without being watered, or by hanging them up from the ceiling.

No plant can live without respirable air.

Now, as by what I have said here, it seems to be probable, that neither water nor soil is, or contains all the true nourishment of vegetables, it must be concluded, that plants must find it in the atmospheric air; for this is the only ingredient without which all vegetables perish. A plant shut up in vacuo soon dies; and it dies in all sorts of aerial fluids which are incapable of supporting animal life—such as fixed air, inflammable air, phlogisticated air, or azote, &c. It is true, Dr. Priestley and Mr. Scheele have propagated a doctrine diametrically opposite to what I have here advanced, by saying that plants thrive wonderfully in putrid air, and perish in pure or dephlogisticated air. This doctrine, though generally adopted, and very ingeniously applied, by Sir John Pringle and others, to illustrate the mutual reference, established by the Author of nature, between the vegetable kingdom and the animal creation, is refuted by my experiments, by which I think I have proved, that plants shut up in vital air live so much the longer, as this air is superior in purity to atmospheric air. I have explained the manner of making these experiments with success; and I have indicated the reason why, of two plants, the one shut up with common air, the other with the same quantity of vital air, (both kept in the dark,) the plant placed in common air can only be kept alive during a certain very limited time, whereas the plant shut up in vital air may be kept alive much longer, even as long as there is vital air enough remaining to cover the whole plant.*

The doctrine of Priestley and Scheele is erroneous on this head.

Why a plant lives longer in vital than in common air.

The relation between animals and vegetables.

From these, and many other considerations, I have deduced, that from the two organized kingdoms, the animal and the vegetable, the animal derives its nourishment from the vegetable; but that the vegetable creation is independent of the animal world, provides for itself, and derives its subsistence chiefly from the atmosphere.†

Discovery of Dr. Priestley about vegetables correcting bad air contradicted by others.

When I engaged in the experiments on vegetables, which I have published, 1779, in English, and, in 1780, more fully in French, Dr. Priestley had already observed that vegetables possessed a power of correcting bad air, which, however, was denied by Mr. Scheele, in Sweden, who found that plants, instead of correcting bad air, corrupted good air. This contradiction struck Dr. Priestley so much, that he employed the summer of 1778 in repeating his former experiments; and, after the most accurate researches, he concluded, that though there seems to be such a power in plants, yet that, very often, they have quite a contrary effect, as Mr. Scheele found; but that he did not know what the reason of this uncertain effect of plants on air was.‡ Dr. Priestley, in 1778, found, by accident, that by exposing well water a long while to the sun, it produced a filmy, greenish sediment, which produced pure air in the sunshine: by examining this matter with a microscope, he found it destitute of organization, and pronounced it to be neither an animal nor a vegetable substance, but a substance *sui generis*, to which he gave the name of green matter. Mr. Berthollet found also, that by exposing dephlogisticated marine acid to the sun, vital air was produced, and Mr. Scheele, in Sweden, found, that the same air was also produced from nitrous acid exposed to the light of the sun.

True reason of the uncertainty of the influence of plants on air.

I was fortunate enough to discover the true reason, why plants did sometimes correct bad air, and sometimes made it worse, which reason was never so much as even suspected either by Dr. Priestley or by Scheele; and indeed if either of them had had the least suspicion of it, their known eagerness for fame would not have allowed them

* See Experiences sur les Vegetaux, tom. II. sect. i, ii, iii, iv, & lvi.

† See Experiences sur les Vegetanx, tom. II. p. 190. 490.

‡ See Dr. Priestley's work *on Airs*, Vol. iv. published 1779, of which the quotations may be found in the preface of my book, *Experiments on Vegetables*, published 1779, p. xxiii—xxxii, and in the Avant-propos and Preface of my *Experiences sur les Vegetaux*, Vol. I. second edition, printed at Paris.

to keep the discovery from the public eye, and Dr. Priestley would not have gone much farther than Mr. Scheele did; viz. to acknowledge openly, (even in his book printed 1779,) that he had been mistaken, and that he was entirely ignorant of the reason why vegetables are so inconstant in their effects on the air in contact with them.*

In what consists the influence of the plants on the surrounding air.

I discovered, in the summer 1779, that all vegetables are incessantly occupied in decomposing the air in contact with them, changing a great portion of it into fixed air, now called carbonic acid, which, being specifically heavier than atmospheric air, tends naturally to fall downwards, and being miscible with moist, salts, and different sorts of earthy substances, is apt to combine with them. I found, that the roots, flowers, and fruits are incessantly employed in this kind of decomposition, even in the middle of the sunshine; but that the leaves and green stalks alone cease to perform this operation, during the time the sun, or an unshaded clear day-light shines upon them; during which time, they throw out a considerable quantity of the finest vital air, and moreover make the air in contact with them purer, or more approaching to the nature of vital air.†

Air decomposed is the principal food of plants.

I did not doubt that this continual decomposition of atmospheric air must have a general utility for the subsistence of the vegetables themselves, and that they derived principally their true food from this operation, by changing this decomposed air into various juices, salts, mucilage, oils, &c. much the same as in graminivorous animals the simple grass changes, in the various organs, into the numerous and very heterogeneous fluids and solids. It would certainly be a very difficult, if not impossible task, to give a clear and satisfactory theory, by which these various changes, compositions, decompositions, new combinations, &c. performed upon one single species of food, such as grass, may be explained. The same incomprehensible transformations are going on in vegetables. If once it was satisfactorily proved, that plants can subsist on what they find in atmospheric air, without any other substance, we ought to content ourselves with the fact alone; for it would be in vain to attempt to penetrate the mystery of all the changes this air undergoes in the organs of these living beings; no more need we anxiously to investigate by what means, in a man who lives only on rice and water, all the various transmutations of this simple food are performed.—This mystery is above the reach of our very limited understandings: and truly, who could pretend to understand how a part of this rice forms in some places hard bones, in others soft fat, and in one single place a liquid, of which a single drop poured into the womb of a woman excites in that organ the most wonderful of all operations—the production of an embryo, which is to bear the strongest mark of resemblance to the man whose sperm gave rise to this progeny.

Impossibility of understanding clearly this mystery.

Important light derived from the new doctrine of chemistry.

Origin of acids from oxygen.

The new light which chemistry has received in our age, affords us the means of understanding many phenomena, which we were either ignorant of, or which nobody understood any thing of before. The new discoveries on the nature of water, air, salts, &c. open the door to an infinite number and variety of new discoveries. The identity of the same principle of all acids called oxygen, which the French chemists have established, throws new light on the difference which exists in the various acids already known, and on the changes which these acids undergo. Thus the same

* See Experiments on Vegetables, p. xxviii, and following.

† I have published facts, which prove that vital air, produced by vigorous plants in the sunshine, is of the greatest purity in itself, and that the air thrown out by them, in the shade, or in the dark, is in itself—that is to say, being free from other air, the most active poison in destroying animal life yet known.—(See my work on Vegetables, French edition, page 182—185.)

acidifying principle, attaching itself to a different basis, *le radical*,* becomes either nitrous, vitriolic, marine, or any other acid: with carbon it becomes fixed air, or carbonic acid; with sulphur, it becomes vitriolic, or sulphuric acid; with phosphorus, it becomes phosphoric acid; with azote, it becomes nitrous acid, &c.—(This last a capital discovery of Mr. Cavendish.) It may thus be reasonably supposed, that some acids taken into our body may lose, in the various operations of our organs, their former radical, and combine with a new one, and by this combination entirely change their nature. Without such like changes taking place in our organs, how could we account for the generation of the great quantity of phosphoric acid existing almost every where in our bodies, (which acid has already got the name, by some eminent chemists, of *animal acid*,) principally in our bones? whereas we find no where the marine acid, though of all others we take in the greatest quantity of it. We find, in several liquids, its basis, the fossil alkali; as in bile, semen, urine, &c.; but we find nothing of its acid, nor even the marine salt, undecomposed, except in the serum of the blood, and the chylus, in which this salt has not yet undergone the elaboration of the vital organs. It seems, therefore, as if all the acids, the marine, vegetable, the carbonic, &c. were in our organs transformed, for the greatest part, into the animal or phosphoric acid. It seems at least probable, that, without supposing this change of acids to take place in our bodies, we could not account for the great abundance of phosphoric acid existing in our bodies; for though it really exists in some of our foods, yet the quantity of it is but small.

Acids changeable in the organs of animals and plants.

If plants imbibe fixed air, or carbonic acid, it is not more difficult to believe that this substance may be transformed, elaborated, or modified into various other substances and salts in the organs of the plants, than it is difficult to believe that the above-mentioned changes take place in the human body. Who could believe, without demonstrative proof, that the aerial fluid, the carbonic acid, constitutes about $\frac{40}{100}$ of limestone, and that this stone having lost its hardness, by being deprived of this aerial fluid, recovers its former consistency by recovering this fluid.†

Carbonic acid constitute about $\frac{40}{100}$ of limestone.

Nature of carbonic acid.

As the carbonic acid is composed of the acidifying principle, the oxygen, and the carbon or coal, plants may derive from these two principles some of the most essential substances we find in them; their acids, their oils, their mucilage, &c. these ingredients, together with the azote absorbed also with the atmospheric air, being elaborated in their organs, variously modified and combined, in a manner somewhat analogous to the wonderful, though to the human understanding incomprehensible, elaborations and combinations which we observe in the bodies of animals.

The doctrine of M. Hassenfratz about the food of plants examined, from his three papers presented to the Royal Academy of Paris.

Mr. Hassenfratz‡ delivered, in the month of June, 1792, to the Royal Academy of Paris, three papers on the nourishment of plants, which met with general approbation. The principal part of the doctrine contained in these three memoires, viz. that *coal or carbon, constitutes the principal nutritive substance of plants*, is much admired, and adopted by the celebrated Mr. *Kirwan*, in his Dissertation on Manures, published in the fifth volume of the Irish Philos. Transactions.

* See Fourcroy's Works.

† According to M. Lavoisier, the founder of the new chemistry, the carbonic acid is composed of $\frac{72}{100}$ of oxygen, which is the basis of vital air, and $\frac{28}{100}$ of carbonic substance, called carbon; water is composed of $\frac{85}{100}$ of oxygen, and $\frac{15}{100}$ of hydrogen; common air is composed of $\frac{27}{100}$ of oxygen or vital air, and $\frac{73}{100}$ of nitrogen, or azote; oxygen air is composed of oxygen, or the acidifying principle, and the matter of fire and light.

‡ See Annales de Chimie, of 1792.

In the first of these papers, Mr. Hassenfratz says, that water and air are not alone sufficient to nourish plants, but that the developement, or growth, of these beings is owing to the *carbon*, which, being originally lodged in the seed, is expended in this business. Doctrine of the first Paper.

In the second memoir he attempts to prove, that the carbonic acid, or fixed air, is not a nutritive ingredient of plants, and that the act of vegetation does not decompose the carbonic acid; but, he says, on the contrary, this carbonic acid is, as Dr. Ingen-housz has discovered, formed by plants in the dark, and drawn from the plants and the oxygen of the water decomposed by vegetables. Mr. Kirwan differs in this respect from Mr. Hassenfratz, and thinks that the carbonic acid is decomposed by the act of vegetation. Of the second.

In the third memoir he asserts, that the carbon, the true nourishment of plants is derived by the roots from the soil, where it is ready found in a state of sufficient solution, or suspension, to be absorbed by the suckers, and carried through the whole plant. He thinks that the vigour of the plants depend chiefly upon the quantity of carbon, with which the soil is impregnated; and he gives the name of carbon to the brown sediment of the infusion of dung which remains after the water is evaporated. Of the third.

The doctrine contained in these memoirs, as well as the important experiments to which they relate, require, I think, farther investigation, before it can be proved or clearly understood. Let me be allowed to throw out some hints and considerations which may, perhaps, shew the way towards the true mystery of the manner which nature employs to feed the plants. All seeds contain a certain quantity of food, by which the plant may be kept alive in the beginning of its growth; some have a considerable portion of mucilaginous matter, such as seed of quince; some have, besides this mucilage, a very thick cover or pulp, by which the seed is surrounded, such as the seed of grapes, apples, pears, melons, cucumbers; which substances serve also as food for animals. All those substances by which many grains are thickly covered, yield a great quantity of fixed air, or carbonic acid, when the seed lodged in them begins to vegetate; but this substance being exhausted at the close of their fermentation and putrefaction, the embryo plants must be capable of providing for themselves. A new born child may also live a few days without food, being nourished by some nutritious matter which it brings with it when born, and which it had imbibed by the mouth when in the womb, and part of which nourishment was prepared in the pectoral gland of the child; as it is well known that all children, male as well as female, come into the world with a portion of true milk elaborated in their own breasts. Thus also the yolk of the egg is drawn into the stomach of the chick when ready to break its prison, by means of which yolk it is nourished, till it has acquired strength enough to go in search of food. The mothers of animals endowed with breasts feed, during a certain time, their offspring by their milk. Many animals, such as birds of different kinds, wander about in search of food, to be carried to their young. Very few animals find on the spot where they exist, every thing they want. But all plants are destined by nature to remain on the same spot, and therefore must possess such faculties which prepare into food some of the substances in contact with them, as soon as they have consumed the small store of food they are provided with before they vegetate. Origin of the first food of plants springing from seeds, compared with the origin of food in young animals.

As the very first decomposition of the pulp surrounding the seeds is accompanied with the production of carbonic acid, and the first operation of the embryon or beginning plant, is to decompose the air in contact with it, by changing the oxygenous part of it into carbonic acid, of which it probably absorbs, in the dark and shade, the oxygen, and, in the sunshine, the carbon, throwing out at that time the oxygen Hints of the final cause of that almost general decomposition of air by plants from

their first existence.

alone, and keeping the carbon to itself, as nourishment: as all these different operations, I say, have one general effect, viz. the decomposing the air in contact with plants, it seems more than probable, that vegetables derive their principal food from this decomposition, and the production of fixed air, or carbonic acid.

This hint farther confirmed by the correction of an error of Priestley and Scheele.

This supposition will acquire a degree of greater probability by considering, that all air which cannot be easily changed or decomposed into fixed air, as possessing no oxygen at all, are true poisons to plants, such as inflammable air, putrid air, and azote, contrary to Dr. Priestley and Mr. Scheele's doctrine; and that vital air itself, or an air approaching to its nature, maintains a plant remarkably well, in its full vigour; and that carbonic acid concentrated, or without a great proportion of respirable air, kills also plants, as this air, and all other airs, poisonous to vegetable life, are also destructive of animal life; which doctrine I produced the first, in contradiction to that of the two celebrated philosophers just mentioned.*

Discovery of the vegetables decomposing air.

When I discovered, in 1779, that all vegetables decompose the common air by night, and change a part of it into fixed air; † and when I drew from this and some other facts, the conclusion, that the plants absorb this fixed air, and turn it into their nourishment, the new doctrine of chemistry was not yet published, and being ignorant of all the beauties of this system, I was unable to reduce these facts to a proper theory. But since we have been instructed in the analysis of water and air, it is become much easier to explain the phenomena of vegetation. As it is now admitted, that fixed air, or carbonic acid, is composed of oxygen, deprived of its caloric, or matter of heat, and of carbon, it is not difficult to understand how plants provide or prepare their own nourishment by producing carbonic acid, supposing it to be demonstrated, that carbon is the principal nourishment of plants.

The difficulty to explain this decomposition is rendered easier by the new system.

This decomposition adapted to the *etiolement* of plants in the dark.

From this doctrine it would naturally be inferred, that plants must grow the most rapidly at such time, when they prepare the greatest quantity of this nourishment, which is when they are in the dark; and this is just what really happens, as all plants grow with much more rapidity in a dark place than in the light, as Mr. Du Hamel and Mr. Bonnet, of Geneva, found; they call this quick growing *etiolement*. Plants, in general, grow less towards the middle of the day than at any other time: many do not advance at all when the sun is near the meridian; some even grow manifestly shorter towards that time. (See my work, Exp. et Obs^ns Nouvelles vol. II. p. 206.)

The growth of plants generally retarded towards the middle of the day.

I discovered that the roots of plants, even when exposed to the sunshine, produce carbonic acid, but that the leaves and green stalks produce this acid only in the dark; and that flowers and fruits, with a few exceptions among the last, produce at all times, even at the roots, carbonic acid. Thus there is no time lost, some parts, or the whole plant, being constantly employed in this business of preparing carbonic acid.

Do plants derive the coal by their roots?

Though Mr. Hassenfratz seems to believe, that plants do not derive the carbon (in his opinion their true nourishment) from the carbonic acid, but finds it ready made in the dung; I think it more probable, that plants derive it chiefly from the carbonic acid, which is a substance very easily decomposable in its two ingredients, viz. oxygen and carbon. All manures, principally dung, produce a great quantity of carbonic acid, either by itself, or by decomposing the air in contact with it.

Difficulty about the plants deriving carbonic acid

But here seems to start up a difficulty, how a plant or manure can draw from the atmospheric air carbonic acid, as common air contains, according to the new system, only $\frac{1}{100}$ of it; and, according to Mr. Lavoisier, nothing at all. Though, according to

* See Experiences sur les Vegetaux, tom. II. Sect. lvi.

† See Experiences sur les Vegetaux, tom. I. p. xc. and xcii.

those principles, it could not be accounted for theoretically, I think we have at hand facts enough from which it seems evident, that the common air can, by itself, furnish all the ingredients for the composition of carbonic acid, as we will see by and by. Do these facts argue a defect in the new system? Let a better judge than I am decide this.

from the atmosphere obviated by facts.

We are as yet very far from understanding the various productions, which in this world are exposed to our senses as offsprings from the infinite combinations, decompositions, chemical affinities, or attractions, &c. every where in action on the surface and in the bowels of the earth, in the atmosphere, the waters of the sea, and all others in the organized bodies of animals and vegetables, &c. The new system of chemistry, indeed, furnishes a vast deal of new light, but is yet by no means sufficient to penetrate in the deep mysteries of organized beings; for instance, the propagation of animals and vegetables has acquired from it but very little light, if any at all. The analysis of the spermatic humour, very easily to be made, affords not the least idea of the nature of its wonderful prolific power. After this digression, I return to the subject of the production of carbonic acid.

Mechanism and process of metamorphosis in organized bodies inexplicable.

Calcareous stones, and alkaline salt, deprived of all their carbonic acid by fire, regain it by the sole exposure to the open air. If this production can happen by such simple means, can we be astonished that organized bodies draw it from the same source, the atmosphere; which to me seems to be the general magazine or store of all the substances which enter into the composition of all organized bodies of the animal and vegetable kingdom, and even of many others of the mineral kingdom.

Mr. Du Hamel found, that a branch of a vine, or any other tree, conducted within a hothouse, its root remaining out of its boundaries, will there shoot forth vigorous leaves, new buds, flowers, and produce fruits, when all the other branches remaining exposed to the open air, shew no signs of life, being, with the roots, benumbed by the cold, and probably destitute of any motion or circulation of their juices. If the growth of vegetables depended on the absorption of carbon by their roots, the branch drawn in a hothouse could not thrive at all as long as the root and stem are benumbed by cold weather.* But this branch, being in contact with no substance but air, heat, and light, must derive from the surrounding air alone all its wants to perform all the operations necessary to its growth and propagation. By watching all its phenomena, as I did, it will be found decomposing the air in contact with it, but in a very different way by day and by night: and that it performs these transmutations of air chiefly within its organs, is the more probable, because all plants absorb the air in contact it, with all its contents,† and throw it out in a given time, much altered from what it was at the moment it was drawn in. The period of time required by a plant to renew all the air it has absorbed, I found to be less than half an hour by day and by night. (See the II. vol. of my work *on Vegetables*, Sect. XXII. XXIII. XXX.)

Air is absorbed by plants night and day, but undergoes within their organs, a different operation at different times, and is renewed at least every half hour.

This last assertion, which I have demonstrated by facts, will perhaps be looked upon by critical minds as somewhat parodoxical, as it seems difficult to conceive, that the same organized body can, at the same time, inhale and evaporate from the same surface the same fluid; but this double phenomena being continually performed in all parts of living animals, the difficulty of understanding it vanishes of course. Though the most part of annual plants which afford good nourishment for men, such

Difficulty in understanding the simultaneous existence of absorption and evaporation, resolved by a comparative fact.

* N. B. As the juices of the deep seated roots can never be congealed by frost, the cold never reaching so far; and as, therefore, the frost cannot congeal the juices of such a vine, but as far as its trunk is exposed to the open air, and a little way under the ground, I think this fact may be explained in a clearer way by the other theory, which the reader will find hereafter.

† I prove this in various places of the 2d vol. (French ed.) of my work on Vegetables.

as wheat, rye, maize, will grow in poor soils, yet they do not become thriving in a luxuriant way, but in what is called rich or well-manured soil. Those plants having a quick growth, when assisted by heat and the sun's light, come very soon to their term, or to the act of propagation of their species, or of producing seed, which being come to perfection the vital power of the plant is exhausted, and it dies. These plants being of a tender structure, and generally not spreading their roots deep in the ground, require the nicest attention in preparing the soil, so that the roots may find the least resistance in spreading, and may find as much nourishment ready prepared for being absorbed by the roots, as the plants want to become vigorous, and no more; as it is well known that too much manure, as well as too little, will prevent the plants from thriving. By want of manure the plant may be considered as starved, and by too much as choked with food. This may perhaps be considered as somewhat analogous to a chick which will lay no eggs, or very few, by feeding it too little or too much; giving it daily, for instance, three or four ounces of good grain, it may lay every day an egg weighing about two ounces; but by cramming it with eight ounces of grain it will lay no eggs at all, or very few (I have forgot this accurate proportion). I believe (by the way) that in feeding animals either destined for food or for labour, the quantity, quality, and preparation of food necessary to obtain the end proposed is too little attended to, and that much food may be saved if this article became the object of an attentive observer. It is very true that some animals take in much more nourishment than they want, such as horses, in whose excrements are often found oats that are so far from having been digested, that they have even not lost their power of vegetation. It is very probable that a horse may be kept in good health and vigour by giving it mashed, ground, or boiled corn in a moderate quantity; malted grain would be the best, as Lord Dundonald thinks. Brown or rye bread is often given to horses in the Low Countries, on the road; the horses like it very much, and become remarkably lively after it; the same effect is obtained by beer and milk, which they also give them on the road. They find a remarkable benefit in the Low Countries by feeding the cows in the stable with boiled turnips, potatoes, and different other vegetables. They keep, by this food, their strength, and afford a great quantity of good milk. It may be with plants, perhaps, as it is with animals, too much food being hurtful to both; a dog and a cat being fed plentifully, loose their natural liveliness, grow fat, and sleep almost day and night.

State of plants in a soil too little or too much dunged,

compared with animals too much or too little fed.

Doubt whether dung contains real coal, as Mr. Hassenfratz thinks.

If coal is really the genuine food of plants, it seems to me doubtful whether the brown mud remaining after an infusion of dung is evaporated, is real coal before it has undergone an ignition. It is, as I think, to be called rather an extract, and may again be diffused through water, or dissolved as it was before the evaporation; but when it is burned into real coal, it is become almost totally insoluble in water, as all charcoal is generally well known to be. Charcoal is not only insoluble, but almost unalterable, incorruptible, possessing only when newly ignited an antiseptic power, which it recovers again by a new ignition; and I cannot help still doubting, whether real coal reduced even to impalpable powder possesses any manifest quality by which it deserves to be arranged among manures. The justly celebrated *Arthur Young* having put this powder to the trial, found it had no beneficial effect at all on vegetation.

Real coal does not promote vegetation.

Farther proofs that plants derive their food chiefly from the atmosphere.

Though there is no doubt but that vegetables draw in by their roots a good deal of food, yet I think the principal business of feeding is carried on by the leaves in the atmosphere. Besides the fact of Mr. Du Hamel described on the preceding page, there are several other considerations which seem to give strength to this assertion. Many

European trees, when stripped at once of all their leaves, will die. (Trees in very hot climates suffer the loss of their leaves by the scorching sun for a time in dry weather, without perishing). I was present at the following fact: the sulphurous smoke from burning a few pounds of antimony mixed with nitre was accidentally driven by the wind upon a very thriving large pear tree, full of pears half ripe: next day I found all the leaves and pears fallen off, and the tree irrecoverably dead. A plant placed under a bell, with its root in a phial full of water, will die when the bell is exhausted by an air pump, it will equally perish if, instead of respirable air, it is immersed in any air unfit for breathing animals. If the roots were the chief organs of feeding plants, their life might be supported in any of those airs, principally such as possess no acrimonious ingredient, as pure azote: but pure azote will kill a living plant, and prevent seeds from vegetation.

Respirable air or oxygen and heat, are necessary to vegetation, not the light.

Respirable air moderately warm is alone sufficient to make a plant vegetate without any light. I found even that seeds are hurt by a strong light, grow slowly, and are often killed, before the two lobes are become leaves, and their plumula or root is formed; and that if they survive the action of light, they remain commonly but weak or deformed plants. This shews, that in agriculture almost all seeds not covered, will perish when the sun shines upon them at the time of their beginning to swell or vegetate. My experiments have, I think, proved sufficiently, that such seeds or embryo plants perish by the light only (which is unsupportable to all very young plants, as well as plants weakened or sickened by transplantation), and not by the heat of the sun, or by want of moist.* When a plant is reared up in the dark, either under the ground, or in a dark or shaded open place, to a certain degree of strength, light becomes more and more beneficial to it; not, however, for its advancing in size, but for acquiring strength, getting a lively green colour, and for its becoming fit for propagating its species, which propagation will not succeed without sufficient sunshine, or at least daylight, and a due degree of heat, that is to say the heat of the air, and by no means the heat of the soil; which last, though very beneficial to some plants, is rather hurtful to several, and indeed the ground being kept moist by watering it, is always kept cool by the continual evaporation; and yet plants in general thrive very well in moist ground, though always kept cool. Trees in a forest spread their principal roots to such a depth, as the heat of the atmosphere never can reach: their roots, are winter and summer in an uniform temperature of 50-52 degrees of Fahrenheit's thermometer. This shews that the vegetation of trees, as is that of almost all plants, being stopped, or nearly so, during the winter, is revived by the heat of the atmosphere alone, without any regard to the heat of the soil, which is scarcely subject to any alteration but at the surface. The heat of the atmosphere alone sets the juices of trees into motion, which motion sets, by propagation also, the juices of the roots into the same motion; thus the juices drawn from the roots upwards empty the filaments and suckers, which by this motion upwards must naturally become powerfully absorbent, without any degree of heat being more necessary for this absorption or attraction than is required for the suction of an ordinary pump. Boyle or Hales (if I recollect well) applying a glass tube to the trunk of a vine cut off in the spring, collected a very large quantity of juice pumped up by the roots, which motion of the fluids in vegetables depends greatly upon their irritability, according to Mr. *Van Marum*; which seems to be the more probable, as an electrical explosion directed through a plant,

Seeds exposed to the light grow very slowly, or perish.

Light hurtful to very young plants.

When light becomes necessary.

The heat of the atmosphere alone revives vegetation in trees and other plants, not the heat of the soil.

Theory of the suction by the roots.

* See Experiences sur les Vegetaux, tom. II. pag. 447.

such as an *euphorbia*, stops immediately all motion in its juices by extinguishing the irritability.*

What is absorbed by the roots is greatly altered in the plant, with some exceptions.

The roots thus absorbing the moist presented to their suckers, take in, of course, all salts, earth, metallic substances, &c. that can be dissolved in water, or in the saline matter to be found in almost all waters. This solvent is found to be for the most part fixed air. Though we find some of these salts with all their characteristic qualities in some plants growing in a soil impregnated with them, as are many plants growing near the sea-shore, which are full of sea-salt; yet it is not less true, that the most part of the ingredients imbibed by the roots as well as by the leaves, trunk, and branches, undergo almost a total change in the organs of the plants, even so far as to produce in one plant a wholesome food, and in another its next neighbour, a true poison. But as I have proved before that the atmosphere alone can furnish to some plants all that is wanting for all their functions, we ought not to look too anxiously among rubbish or dung, for the true and natural food of vegetables, though in those substances a greater quantity of this food is at hand ready prepared, and partly imbibed in the form of carbonic acid, mucilage, oily and saline matter, by which the plant is enabled to provide food for throwing out and nourishing more branches, flowers and fruits. I think it difficult to conceive how a large tree finds, during centuries, nourishment on the same spot, in the supposition of Mr Hassenfratz, that its principal food is coal; and that this coal is not derived from the decomposition of the carbonic acid (of which coal constitutes nearly one-third, according to Mr. Lavoisier $\frac{28}{100}$). That gentleman admits my discovery as well-founded, that plants produce carbonic acid in the dark; and that roots being always deprived of day light are of course incessantly occupied with this business. There exists every where in the soil common air, and common air alone is sufficient to furnish, as I have proved before, carbonic acid, even without plants. Thus there is no difficulty in tracing the source of this coal, and of conceiving how the largest tree finds, during centuries, that immense quantity of food it requires for its maintenance, growth, and abundant production of fruit or seed, all which is certainly derived in part from the soil; but I still believe chiefly from the atmosphere, by means of the leaves absorbing and decomposing the air in contact with them. In the sequel of this paper, the manner by which the roots of trees beget carbonic acid will be further traced.

Difficulty of conceiving the nourishment of trees in the system of Mr. Hassenfratz.

Solution of this difficulty.

The transmutation of air into all kind of bodies is a very ancient doctrine.

The transmutation of common air into different solid bodies, such as plants, is a very ancient doctrine; Pythagoras and Epicurus took this for an undoubted fact, and Lucretius, who has adorned his poem de *Rerum Natura* with his doctrine, says that air changes continually into different other substances, and that these are again decomposed into air, which afterward returns again into the composition of the different bodies; and that if this incessant rotation did not exist, every thing in this world would have been changed into air, which of course would have been at last the only substance existing.—These are his words:

Aëra nunc igitur dicam, qui corpore toto
Innumerabiliter privas mutatur in horas.
Semper enim quodcumque fluit de rebus, id omne
Aëris in magnum fertur mare, qui nisi contra
Corpora retribuat rebus recreetque fluenteis,

* See Lettre 2d de Mr. Van Marum à M. Ingenhousz, dans le Journal de Phisique de M. Lamethery, pour l'anne 1792.

Omnia jam resoluta forent et in aëra versa.
Haud igitur cessat gigni de rebus, et in res
Recidere assidue, quoniam fluere omnia constat.
Titi Lucret. Car. de Rerum Nat. Lib. V. v. 274.

Anaximenes said that all bodies are made of air.

Theory of the *Eliolement*, or the accelera-tion of growth in the dark.

On a preceding page of this paper I hinted at a new theory of a curious fact, viz. that plants accelerate their growth in the dark, and advance the least in the middle of the day (which is an observation of Mr. Gardini). Though this theory may perhaps be erroneous, yet as it is supported on a real fact, I may be permitted to say further, that plants changing in the dark more respirable air into carbonic acid than they can digest, they throw out a large quantity of it, and thus render the air in contact with them less respirable, and that in the day they absorb with the atmospheric air so much matter of heat and light, or caloric furnished by the sun, that they cannot all digest it, and therefore throw it out as superfluous, combined with the oxygen, which has thus acquired the nature of vital air, which vital air, though not yet obtained by plants in its greatest purity, is, however, in itself full as pure as is that which we obtain from the best manganese or any other ingredient. (See my book on Vegetables, French edition, Vol. II. p. 182.)

Air elaborated by plants is of the greatest purity.

The true food of plants to be found out by examining their food fur-nished by na-ture to plants when first en-gendered: and by ana-logy drawn from animals.

In a letter to Sir John Sinclair, dated Dec. 2d, 1794, I quoted as a proof of carbonic acid being the principal food of plants, the fact I discovered, that the wonderful apparatus which a plant produces when it is occupied with the propagation of its species, viz. the flower, is incessantly producing carbonic acid. By this observation we may be led to the knowledge of the true natural food of vegetables; and it may be said as a further illustration, that if we were desirous to know what is the natural food of some particular animals, one of the surest methods to find it out would be, to observe what kind of nourishment the parents bring to their young. Thus we should find that a pigeon is best fed by grains, and a swallow by insects. By a similar conclusion I may infer, that the true or principal aliment of plants is respirable air decomposed. By examining the air thus decomposed, I found it consist of two substances, viz. of fixed air or carbonic acid, and phlogisticated air or azote (see my book on Vegetables, French edition, Vol. I. p. xc, and in different other places of Vols. I. and II.); but as carbonic acid contains two distinct substances, viz. coal or carbon, and oxygen, it may be questioned what ingredient of the two is the real food we look for. Mr. Hassenfratz thinks it is principally coal; though his opinion is that the plant does not derive the coal from the carbonic acid, but from the soil or dung; I am much inclined to think that both these substances serve as food; and I am moreover inclined to believe that the azote enters also the plant, and has also some share in feeding it. One of my reasons to think so is, that plants absorb continually the whole of the atmospheric air;* and that in separating this fluid by decomposition into its constituent parts, they throw out that part of it that they cannot all digest at the time it is produced, viz. at night the azote and the carbonic acid disengaged one from another, or only mechanically, not chemically, as formerly they were mixed, and in the sunshine the oxygen almost alone, the carbon and the azote remaining within the plant at that time. Though I think it probable that the azote enters in some way or other into the composition of plants, yet I think it is not absolutely necessary for a plant, as a plant thrives admirably well without it, viz. in pure

Is oxygen and azote also a food for plants?

* See Vol. II. of my work on Vegetables, French ed. p. 92—94. and following; as also page 181, 173, 186, 504.

oxygen. It is true, however, that plants also die in pure carbonic acid, but in this case the plant may be perhaps considered as if it were choked with it.

This theory is not yet brought to a demonstration.

I acknowledge very readily that the just-mentioned theory has not all the clearness I should wish to give it. The facts, however, quoted to support it, though contradicted during twelve years, are now admitted publicly, even by those who have been the principal champions and the most violent (even to declare my new doctrine to be a downright *calumny against nature, to be revenged by nature itself)* against it.

The circumstance common to all manures is producing carbonic acid.

Necessary attention in manuring.

In what state dung is to be applied.

How it operates.

As all the most powerful manures have one common quality, viz. to contain or to disengage a great quantity of carbonic acid; and as dung applied too liberally injures vegetation, it seems to be probable, that the principal attention in manuring ought to be directed to the time of applying it to the soil, which is when it is in the height of its putrid fermentation (the acid and vinous fermentation preceding the putrid fermentation cannot be observed in dung, as they pass too quick to be observed, or perhaps do not happen at all in a substance so highly putrifiable); and indeed the most skilful husbandmen think so, and practise it. Thus the great force of putrefaction, which would at last have destroyed the whole ferment, being checked by spreading the dung over the land, or ploughing it in, begins anew in a more moderate way, by the help of warmth and moist, at a time when the growing plants may absorb the fixed air or carbonic acid, either as it is when just formed, or as it is being incorporated with moist or other substances, such as different salts, and earths, of which various kinds are to be found in almost all soils; which substances brought in close contact by moisture, act on one another chemically; that is to say, by various combinations, attractions, or simple and double, or compound chemical affinities. Of all those species of *synthesis, analysis*, and attraction, an almost constant attendant is the disengagement of carbonic acid.* Animal and vegetable substances probably act as manures only, when in the act of decomposition by putrefaction, during which period a great quantity of carbonic acid is produced. This putrefaction is promoted by almost all salts when mixed with those substances in moderate quantities, but is checked by a large proportion of those salts, as Sir John Pringle found. It is thus

How animal and vegetable substances act as manures.

Hints on the final cause of the promiscuous production of carbonic acid.

* If we cast our regards with astonishment on the vast scene of that perpetual rotation of organized beings, changing continually one into another by acquiring life, and disappearing by death: when we consider that all living animals, by their respiration, perspiration,† digestion of their food, by the putrid fermentation of their bodies after death; that all vegetables as long as they live, as well as when they are in a state of decomposition after death; that, in short, all the operations of an infinite variety, every where obvious on the surface of the earth, have one general effect that of producing carbonic acid, even in the middle of putrefaction, by which volatile alkali, now called *ammonia*, is chiefly produced. If we add to this consideration, that even the inorganized bodies, those of the mineral kingdom, have in many instances, as we have already hinted, a considerable share in assisting the two other kingdoms of nature in preparing this aërial fluid; if we consider, I say, that all these innumerable operations conspire as it were, in producing one general substance; is it possible to doubt, that this fluid, the carbonic acid, has an utility as extensive in this world as is its almost universal production?

Why it is scarce or not found in the atmosphere.

But it may be asked, why is it not to be found in the atmospheric air, if it is almost every where produced? The reason, I think to be, that as soon as it is generated, that is to say, as soon as the carbon is combined with the oxygen, and the caloric dissipated, it ceases to be intimately combined with the atmospheric air; having acquired a superior specific gravity, it quits the common stock, sinks to she ground, and becomes easily miscible with moist, different salts, &c. and thus it disappears almost as soon as it is produced, and becomes, perhaps, the first step towards the transformation of common air into solid bodies.

† See my book on Vegetables, p. 133. English ed. The article is, *on the nature of the air oozing out of our skin.* Dr. Priestley denies absolutely all aërial evaporation from the surface of animals and plants. Some very recent writers seem to claim this aërial evaporation from our skin as a new and their own discovery.

with alkaline salts, with common salt, gyps, &c. which last is a vitriolic salt with an earthy basis. This notion may account for the benefit which the Germans and the Americans derive from employing gyps as a manure. The latter find it even worth their while to draw this ingredient (gyps) from Europe. I believe, however, that of all salts the alkaline salt would be found infinitely superior to any other salt, for the reason mentioned in my letter to Sir John Sinclair.

How salts and stones, such as gyps, act as manures.

According to these notions, we may perhaps understand, why all those manures which undergo the quickest decomposition, ought to be oftener applied than some others, which, not being susceptible, but of a very slow decomposition, such as chalk, lime, burnt and pounded bones, gyps, impart during several years the soil with prolific quality.

Why some manures are oftener to be renewed than others.

We may also understand why quick-lime renders the soil more prolific than limestone; chalk being deprived of its carbonic acid, attracts it readily again from the atmosphere by the help of moisture; but the carbonic acid is strongly attracted by water in which limestone is dissolved, and by this attration the carbonic acid enters also the lime, which is by this combination precipitated, and being thus infinitely divided, is become easily penetrable by all acid, which dislodge again the carbonic acid from it; whereas limestone, whose texture is not loosened by fire, is naturally not so easily decomposed by the action of acids which it may meet in the soil.

Why lime is preferable to limestone.

It has a long while struck me with wonder, that the excrements of horses and cows are almost alone preserved (and that even in general with little care) for manuring, and that human excrements, which are infinitely richer, are too much neglected, many privies being so constructed, that either the whole is lost in common shores, or the most enriching part of it, the salts contained chiefly in the urine, sunk in the ground, or running to waste. We ought to learn from the Chinese how to preserve these precious relics of our digestions, and to restore them to the soil, on purpose to be metamorphosed by it into new food. I make no doubt but that if none of a man's ejections were dissipated, but employed in due time on the soil which was allowed to him to draw exclusively his victuals from, this soil would be so much fertilized by it, as to afford by proper labour more than sufficient food to nourish him. The alvine and urinous ejections of one day, kept together and well mixed, are more than sufficient to dung abundantly for a whole season four square feet of ground. Now on a space of four square feet will grow more potatoes or other vegetables, than a man could well consume in one day; by selling some of this superfluous portion, he may purchase what is necessary to make his potatoes, or food exchanged for them, palatable. The Chinese neglect the dung of horses and cows as we do our own dung, but they provide every where covered reservoirs for storing up, what we drop uselessly in the privies, and the streets.

Observations of human excrements as a manure.

The Chinese are more skilful than the Europeans in manuring their fields.

Page 1. of this paper I have advanced, that some plants derive the most part of their watery substance from the surrounding air. This assertion is not difficult to prove, by considering that all organized beings possess the faculty of producing cold in a medium hotter than their own temperature, and of engendering heat in a medium colder than is their temperature. Mr. John Hunter has demonstrated that trees produce heat in cold weather. Nothing is easier to prove, than that all plants produce also cold in hot weather, and that some possess this power in a more conspicuous way than some others. The feeling alone of a leaf of a vine in the sunshine, will convince any one that it is colder than are the leaves of the most part of neighbouring plants. The continual evaporation of plants, no doubt, has its share in producing this cold; but there is little doubt that this cold is chiefly produced by the vital organs of plants, and the construction of the leaves. A bason full of water will

How plants draw water from the atmosphere.

Analogy between animals and plants in producing heat and cold.

By what means plants are kept cool in the sunshine.

become sensibly hotter in the sunshine than the leaves of some plants, though there is infinitely more evaporation from the surface of the water than there is from the surface of the leaves of plants; it seems the intention of nature to prevent leaves of plants receiving too much heat, has been fulfilled partly in that part of the leaves which alone is destined to receive the direct rays of the sun, it being of a smoother texture than the opposite surface, so as to appear almost as if it was covered with a coat of varnish; from which the rays of light are rather reflected than absorbed. We know that a bright metal will receive but little heat from the sunshine, and that a piece of black cloth will be sooner heated in the sunshine than a piece of white cloth; a green piece of paper hung in a vine will receive more heat than a leaf of the vine of the same colour.

In what manner the plants imbibe moist.

The production of cold by vegetables is of more importance than one would at first sight imagine, as it is chiefly by this faculty that plants are enabled to draw in a part of their moisture, which enters the plant in two different ways; 1st, together with the air in which it is dissolved, continually drawn in by all plants, as I have proved in my second volume *on Vegetables*; 2d, it is absorbed by plants, being left or precipitated on their surface, in a way imperceptible to our senses, by the coolness of the plant, in the same manner as the moist of hot air is precipitated on the surface of a decanter full of cold water, or ice.

Moist is an essential ingredient of air.

Air never is nor can be without water, which exists in it in a double form.

1. As water itself is a composition of two airs, vital and inflammable, or oxygen and hydrogen, in which two substances, Mr. Lavoisier found means to analyze water, and which analysis, as far as it regards the oxygen, I affirmed in my first volume on vegetables, to be performed by Vegetables, with the assistance of the sun, even before Mr. Lavoisier, as I think, published his Analysis.

2. Air, however dry in appearance, has always a considerable portion of water combined with it, in a manner analogous to the solution of salt in water. The water thus adhering to air, is easily separated from it by various means, chiefly by cold; see page 157 of Vol. II. of my work *on Vegetables*, French edition, I quote a simple experiment, which shews that the driest air contains always a great quantity of moist.

Plants absorb and evaporate at the same time an aërial and watery fluid.

That leaves of plants absorb and evaporate at the same time moist and air, is not more difficult to be understood, than that all internal surfaces of our bodies are incessantly moistened by a liquid transuding upon them, and that at the same time a part of that same humour should be continually reabsorbed, and returned to the general mass of humours.—In the 3d article of Vol. II. of my work on Vegetables, and in some other places, I have, as I think, demonstrated that such a simultaneous absorption and emission of air is continually going on in all vegetables.

How this may be accounted for.

I think it is not worth while disputing whether this simultaneous in and exhalation is carried on by distinct inhaling or exhaling vessels, or by the same vessels assuming both functions alternatively. It is not improbable that absorbent vessels in animals should also carry on the functions of transpiring vessels; or in other words, that absorbent vessels should have sometimes an inverted or retrograde motion. This is the opinion of Dr. Darwin, and of several other men of high reputation.

Animals and plants evaporate and absorb moist and air. Priestley denies the last.

Dr. Priestley denies absolutely all emission of air, as well from the skin of animals as from the surface of plants. I think, however (as I have already insinuated in the former note), I have proved the existence of this emission from both, and even that our skins evaporate fixed and azote air. See Vol. I. of my book on Vegetables.

The use of fallows.

The economy of vegetables, as far as we traced it in the former part of this paper, may lead us insensibly to farther reflections, and to trace the reason, why the soil seems to be almost exhausted after it has produced certain vegetables, so as to have

induced the cultivators of most all countries to leave the ground at rest for a whole year. Some lands require even two years rest to recruit their former power of nourishing the same sort of plants. Some plants exhaust the soil more than others; thus flax impoverishes the soil to such a degree, that in the countries where the finest flax is produced, such as in the country of Waas in North Flanders, and in the vicinity of Valenciennes, the value of one good crop is equivalent to the value of the land itself, and it is often sold for this value, which could not be the case if the ground was able to produce every year a tolerable good crop of the same plant. Virgil knew this difference of plants very well, saying, that flax, oats, and poppies exhaust (burn) the soil.—

Some plants exhaust the soil more than others.

Urit enim lini campum seges, urit avenæ:
Urunt lethæo perfusa papavera somno. Georg. I. v. 77.

The ancients knew this.

The ground laying fallow is, however, very far from having lost the power of nourishing different plants; for, if it is left untouched, it will be found full of weeds, which owe, in a great measure, their origin to the dung of horses, and other cattle, which contain a vast number of indigested seeds of various plants. The superior wisdom of the Chinese (as we have already hinted) and the Japanese is very conspicuous on this head, as it is in many others, by preferring human dung (which contains none of such seeds) to that of cattle. Their fields are, for this reason, at least in a greater measure, so free from weeds, that a celebrated botanist, passing lately through Japan with the Dutch embassy, could scarce find any other plants on the corn fields, but the corn itself. But in these countries the laws prohibit the neglect or waste of all human excrements, and every house has proper reservoirs for this important ingredient, of which, perhaps, not $\frac{1}{10}$ part is preserved in the most part of Europe, and principally in this country, which is considered as the most enlightened and best governed of whole Europe though in the middle of real distress for corn, (of which it sometimes imports a million sterling's worth in one year,) it throws away the substance the fittest of all for multiplying corn; and it suffers, moreover, one-third of all the arable lands to lie without cultivation or inclosure.

Principal origin of weeds infecting the corn ground.

How the Chinese and Japanese prevent the weeds.

How to remedy this mischief in Europe.

Reproach to the English nation about the waste lands.

The utility of fallowing seems hitherto not to be well understood, any farther than ancient custom, founded on experience, has propagated the practice from father to son. The benefit derived from this practice, is commonly attributed to the utter destruction of weeds, by ploughing up the ground several times, and to the action of the atmosphere on the soil. It seems to me somewhat doubtful, whether the ancients considered the ploughing up of the ground so necessary in fallows as we do; as Virgil, whose superior skill in the husbandry of his time is generally acknowledged, speaks of the utility of fallowing, as consisting only in leaving the ground at rest, without stirring it by the plough; which rest he even prefers to the rotation of crops.

In which consists the utility of fallowing.

Sic quoque mutatis requiescunt fœtibus arva.
Nec nulla interea est *inaratæ* gratia terræ. Georg. I. v. 82.

Nature of fallows according to Virgil.

The first of these benefits, that of getting rid of the weeds, which multiply themselves by propagation, is evident enough; but it has not yet been determined, what operation the atmosphere performs on the land to restore its fertility. Those who have attempted to find it out by analyzing the soil before and after the fallow, have laboured in vain. I imagined a long while ago, and told it to several of my acquaintances, that an inverse way of examining this mysterious influence of the incumbent air on the soil, may possibly be the best, if not the only way to unriddle this diffi-

How to find out what the soil gains by fallowing.

culty; that is to say, to examine, not what the soil had gained, but what the incumbent air had lost.

Historical account of Dr. Ingenhousz's proceedings in tracing this pursuit.

When, in 1779, I engaged in the research on the mutual influence of the vegetable kingdom upon the animal creation, or on the relation which exists between the two organized kingdoms in regard to the common element of both, the atmospheric air, I took not so much notice of what happened to the plants themselves, when confined with their own element, as what happened to the air confined with them in the light and in the dark, I contented myself, as to the plants, with finding that they suffered nothing by having been shut up with their own element during some hours. But on purpose to make the following reasoning more coherent, I must beg leave to make a short recapitulation of some articles already explained in the former part of this paper. After having satisfied myself about the safety of the plants, I found, by examining the air shut up with them, that it was affected by the plants quite differently in the day light from what it was in the night, or even in a dark place in the middle of the day time. I found that the plants communicated by day time to the air in contact with them, oxygen (vital air) or the general acidifying principle, of which the atmosphere contains about $\frac{27}{100}$, and that at night, or in a dark place by day, they communicated to the air in contact with them fixed air, now called *carbonic acid*, which is composed of the same acidifying principle combined with coal, *carbon*, to which it has a great attraction or affinity.

How plants draw from the atmosphere the oxygen and carbonic acid.

I inferred from these, and some other facts quoted before, that the plants, in the common course of nature, draw from the air, in a great measure, what is necessary for their subsistence; and that, being thus incessantly occupied in decomposing the common air, they render a part of it miscible with the ground, or with substances inherent in the earth, such as moist, salts, &c. that the carbonic acid, which is now admitted (according to my original idea) as a nourishing substance for plants, is prepared, without intermission, day and night, by the roots and flowers, and in the night by the leaves and the rest of the whole plant, must have been destined by nature to some important use for the plants themselves. An utility, whose importance must be equivalent to the wonderful action by which it is produced, not only by the plants, but by an almost universal operation carried on all over the surface of the earth, at the time principally when all vegetables want the most nourishment. Being full of this persuasion, I thought it very probable, that the soil itself must also have its share in contributing to this almost universal process of nature. By putting this my suspicion to the test of experiments, I found that the soil, even without the assistance of any plant, is incessantly employed in drawing this general and acidifying principle from the incumbent air, and in changing it into carbonic acid, by furnishing it with carbon, of which the ground is never deficient; that the soil performs this decompostion of the air, night and day, though more powerfully by day, and in warm weather, than in the dark, and in cold weather; and that this decomposition is sometimes so powerful in good garden ground, that it counteracts even the influence of the most vigorous plants in the sunshine; so that the earth of a flower-pot communicates sometimes more carbonic acid to the air, confined by a glass bell (with which the plant and the flower-pot are covered) than the plant had communicated oxygen; which oxygen, being absorbed at the same time by the soil, the remaining air had lost more of its oxygen by the attraction of the soil, than it had acquired by the presence of the plant. See my Experiences sur les Vegetaux, tom. II. p. 119. 188. 438.

The soil itself has a share in this decomposition of common air. Experiments made to prove this assertion.

Other facts to prove this assertion.

Eight cubic inches of good mouldy ground, without manure, exposed in a tea saucer to the contact of eighteen cubic inches of atmospheric air during three days and

nights, in the summer, the weather being agreeably warm, but constantly hid from the sun-light, by covering the aparatus with a flower-pot, had contaminated the air to such a degree, that a wax taper could not well burn in it. One measure of this air mixed with an equal measure of nitrous air, in the eudiometer described in my work on *Vegetables*, was reduced to one measure, and six-and-thirty hundreds of a measure; whereas one measure of atmospheric air mixed with an equal measure of nitrous air, was reduced to one measure and two hundred parts of a measure. A similar quantity of the same soil, confined with the same quantity of air, the apparatus being left uncovered, so that the sun did shine upon it during the most part of the day, had injured the air still more, so that this air had lost the most part of its oxygen. At the same time I exposed two similar quantities of common air to the action of eight cubic inches of well manured garden mould, one of these apparatus being exposed to the sunshine, the other being covered all the time by a flower-pot. By examining the air of them, it proved to be still more injured than the air of the two former apparatus, principally that which had been exposed to the influence of the sun's light; so that this air having lost almost all its oxygen, was changed nearly into pure azote, mixed with some carbonic acid, of which acid I found manifest signs by lime-water becoming troubled when shook with any of those four airs.

Conclusion that the soil draws the general acidifying principle from the atmosphere.

All this shews, in a manifest manner, that the soil draws incessantly from the incumbent air the oxygen, the general acidifying principle. There can be, I think, little or no doubt, that what happens to air shut up with earth, happens also to the air floating continually over the surface of the earth—that is to say, that the soil draws incessantly some oxygenous particles from the air sliding over it; so that, in the course of a whole year, a soil, principally when ploughed up several times, must have attracted a considerable quantity of the acidifying principle, principally mouldy ground, in which some decayed vegetable or animal substances capable of farther decomposition exists. Siliceous sand, either dry or moist, does scarce or nothing at all injure the air in contact with it; neither is air materially affected by being shut up with pure water. Now as all acids derive their acidity from the oxygen, of which the common store exists in the immense ocean which surrounds our globe, the atmosphere, is there not some probability that it would be possible to restore, in a moment, to the soil, what it can acquire in no less than a whole year from the incumbent air when left to itself?

What is required in the soil to extract this principle from the air.

Application of this doctrine to discover a very simple substitute for fallowing.

Effect of the rain on the ground already oxygenated.

When the soil has acquired from the incumbent air a considerable portion of oxygen, either as it is existing in the common air, or combined with carbon, with which it constitutes carbonic acid, the rain will certainly carry a great deal of it to the deeper strata of the ground, and thus rob in part the superior stratum of the ground of the full benefit of this useful substance.—But if by this the surface of the ground should even become almost entirely exhausted of it, it would soon recover it again from the same source, and that even in a more powerful way than it did before the rain; because the soil, when perfectly dry, has little action, if any at all, on the incumbent air. In the mean time that rain carries with it to the bowels of the earth a great deal of the ingredients useful to superficial plants, these ingredients are not lost to the vegetables in general, as they are absorbed by the deep-seated roots of trees, which roots, though incessantly occupied themselves with shifting from the air, always existing in the ground, the carbonic acids (See my work on Vegetables) must acquire by this conveyance a fresh and probably a necessary supply of it.—Besides this power of shifting carbonic acid from the air by attracting its oxygen and furnishing it with carbon, plants possess a most wonderful faculty of changing

Plants possess more than one way of procuring oxygen, viz. by decomposing the air and the water itself.

water itself into vital air, or oxygen; which I have maintained as early as 1779.—(See my work on Vegetables.)

How it may be accounted for that plants draw carbonic acid from the atmosphere, which does not contain any itself.

I have, as I think, sufficiently demonstrated, by facts, in the preceding part of this paper, that not only vegetables, but the soil itself (even as caustic alkalies and quick-lime), have a power of extracting the carbonic acid from the atmosphere; though the French chemists assert, that common air contains in itself no carbonic acid at all; which is not easily to be accounted for but by considering that there is in this world, going on an incessant rotation of beings, by the continual new combinations, attractions, mixtures, and affinities, in animated and inanimated beings.

Why a fallow imbibes more oxygen than ground covered with plants.

It seems to be more than probable, that the soil, laying fallow, attracts from the incumbent air more of the acidifying principle than it does when covered with plants; as at that time the contact with the air is partly hid from it, and as the vegetables themselves take it in, in proportion as it is formed.

Easy method to impart oxygen in a moment to exhausted soils by concentrated acids.

Would it not from all these considerations taken together appear probable, that the oxygenous principle may be in a moment imparted to an exhausted soil, by pouring upon it, a little before the sowing of fresh corn, one of the most concentrated acids, much diluted by water or divided among a heap of earth? I am of opinion, that the first trials, if thought worth while to be made, should be made with concentrated muriatic, or vitriolic acid, principally the latter, by mixing it with a sufficient quantity of water, or of dry sand or earth, so that it may be thrown or scattered over the ground as corn is usually sown. We know with sufficient certainty, that vitriolic acids (even as all other acids) is nothing else but the acidifying principle, drawn from the atmosphere by the burning of sulphur, and partly from the nitre added to the sulphur, to assist the inflammation of it by continually furnishing it with fresh oxygen, without which no flame can exist.

How to apply the acid.

Analogy between acids and oxygen.

Why the oxygen quits the air and becomes a powerful acid.

This acidifying principle retains its aeriform nature as long as it is combined with a due proportion of *caloric*, or the matter of heat, which is considered as the general principle of fluidity of all liquid bodies; which *caloric* being consumed in the burning of the sulphur, the oxygen can no more retain its form of air, and allies itself with the sulphur as with its basis, and constitutes the sulphuric acid, in a similar way as this very oxygen, when combined intimately with azote as its basis, constitutes nitrous acid, and with phosphorus phosphoric acid.

How oxygen is changed in different sorts of acids.

Though I readily acknowledge that this hint is only deduced from theory and analogy, I cannot help thinking, however, that by some agricultural philosophers it may meet with some attention, or be considered as deserving a trial in various ways. Being in possession of no facts which could serve as proper guides how to proceed in such trials, I can only throw out some loose hints, the product rather of imagination than founded on experience. Having no ground at my disposal, I could only make some preparatory experiments, which, as far as they go, were rather encouraging than derogatory to my scheme. I made them last year with my friend, the Hon. Baron Dimsdale, M.P. in his father's garden. I poured about one dram of oil of vitriol, diluted in a pint of water, in a ridge about two inches deep and three feet long; immediately after, I sowed in it twenty grains of wheat, and covered them with earth. I sowed also twenty grains in another similar ridge, on which I poured the same quantity of diluted oil of vitriol. These mixtures fermented very violently with the soil which contained a great portion of calcareous earth. A part of the calcareous earth was thus changed into gyps minutely divided, resembling a whitish powder. I repeated this, in other spots of the garden, taking, instead of wheat, oats, rye, and barley. This was also done in some flower-pots. Though the quantity of acid was

Account of some preparatory experiments.

in these little experiments much greater than what I would have employed on a field, yet the general result was, that, very far from having hurt the vegetation of the seeds, we found the plants all very thriving, and in the most part of these spots the plants came out earlier than those which were not manured with acids. The marine and the nitrous acids had a similar effect as the vitriolic. The plants thus treated were neither retarded, nor weaker than others, but rather stouter or more vigorous for the most part.

Loose hints how to proceed.

Though I can say nothing with any good reason about the quantity of acid to be employed on each acre of land, yet if I had the free disposal of some land, I would begin by scattering on one acre twelve pounds of concentrated oil of vitriol diluted with water, or rather divided among a heap of dry sand containing little or no chalk or other calcareous earth; on another acre I would employ nine pounds; and on a third six pounds, which, at the rate of 4*d.** the pound, would come to 2*s.* per acre. If any advantage should be observed from it, some attentive farmers would soon find out the most advantageous proportion of this ingredient on different sorts of land.

In which consists the benefit to be expected from the project.

It would be useless to occupy ourselves with a particular theory to explain the effects of acids on the soil, after it is demonstrated that, in the natural course of things, the atmosphere imparts to the ground the very same acidifying principle which constitutes not only the vitriolic, or sulphuric acid, but also all other acids. Thus the only difference between leaving the land in fallow, and sprinkling it with a powerful acid, would be, that in the first case a whole year's crop is lost in waiting for the slow operation of the atmosphere; whereas, in the proposed method, all that the air can grant in a whole year may be communicated all at once to the ground.

I would advise to destroy the weeds as soon as possible, by ploughing at shorter intervals, at the ordinary depth, and give the land, a day or two before sowing, a superficial ploughing, and break as much as possible the ground, after which the acid should be scattered on the soil, and soon after the seeds committed to the ground.

The first trial to be made with summer crops.

I think the first trials should be made with grain, to be sown in the spring, through fear that the rain would carry away the benefit in the winter.

No fertile soil without calcareous earth or magnesia.

There is, perhaps, no fertile soil which has not a portion of calcareous earth, or magnesia, or of both. These two ingredients absorb very readily any acid, principally vitriolic or sulphuric acid. With the first (the calcareous earth) it constitutes gyps, with the second Epsom or bitter salt; in the alliance with either of them, a vast quantity of carbonic acid is produced, which is easily retained by the moist of the soil, and ready to be taken hold of by the vegetables as their food.

Hints on extending the proposed practice.

Could this acid not be serviceable in increasing the fertility of land in general, and restore all at once the fertility of the soil, exhausted by some very impoverishing plants, such as flax?

How to proceed in making the first trial of the new scheme of oxygenating the soil.

If I had land at my disposal, I would not hesitate to oxygenate (as a trial), in the way already explained, all such pieces of ground as were destined to lie fallow during the next season, and to sow corn on it. The loss, if it should not answer the expectation, would be trifling, but the advantage would be considerable if it should succeed. I hope, however, that some intelligent farmers will put the project immediately to the test of experiment for the next season. I would advise thereabout the following method: to plough up several times a piece of ground; for instance, an acre, on purpose to destroy the weeds, and to bury them under the ground, where they act as manure; then to divide this spot into five equal partitions, four of which to be

* Concentrated oil of vitriol was sold, a little while ago, in England and in France, at the rate of three-pence the pound, by bottles containing about 150 pounds. It is now sold at the rate of fivepence, at the time this paper was in the press, in Feb. 1796. Concentrated marine acid was sold for about the same price.

manured in the usual way, and then oxygenated as directed below; on the fifth no manure nor acid should be employed, as this partition should be destined as a standard or a comparative experiment. On each of these five pieces of ground an equal portion of corn should be sown in the usual way. On one of the four partitions to be oxygenated I would sprinkle about two pounds of concentrated oil of vitriol diluted, on the second three pounds, on the third four pounds, and on the fourth five pounds. The time of the rise and progress, as well as the exact quantity of grain to be gathered, should be exactly taken notice of. By such an experiment the advantage or disadvantage of this new scheme would be known at once as to the renovation of soils destined to lie fallow, and the quantity of acid the most advantageous.

Observation on the price of oil of vitriol.

If the project should succeed, a temporary rise in the price of the vitriolic and marine acid may possibly be the consequence; but the discovery of making oil of vitriol from one of the most abundant ingredients of the world, sulphur, would soon reduce it again.

Caution to be observed in the choice of vessels.

In the choice of vessels to be used to spread vitriolic acid on the soil, it is to be observed that iron ones would soon be destroyed, as vitriolic acid attacks iron very violently, but as it does not destroy lead, common tin watering pots could be lined with sheaths of lead. I would give the preference to wooden vessels.

POSTSCRIPT.

Beneficial effect of alkaline salt.

As I have made mention, more than once in this paper, of a letter I wrote to Sir John Sinclair, dated Dec. 2d, 1794, on different articles relating to agriculture, and among others, on the beneficial effects of alkaline salts in promoting vegetation, and respecting the effect of some other salts; and as that letter makes no part of this paper, I think it proper to inform the reader, that the particularly good effect of alkaline salt was so manifest in my own garden, that all the gardeners who saw it, thought it equal to the effect of the best dung. I repeated the application of that salt last year (1795) at Hartford, with the Hon. Baron Nath. Dimsdale, M. P. in his garden, and that gentleman was equally convinced as myself, of its manifest good effects. We tried, at the same time, the application of different neutral salts, the particulars of which experiments I may possibly publish on some other occasion. We made also many experiments with different solutions, and medicated liquids poured upon the ground, as well as steeping the seeds of different grains in them. Be it sufficient to say here, that of all the neutral salts we tried, the Glauber salt did seem to be one of the best in promoting vegetation; and that the steeping the seeds in water impregnated with oxygenated marine or muriatic acid (which is now much employed in bleaching linen in an expeditious way), had a particularly beneficial effect in producing vigorous and early plants. The beneficial effects of these different substances may be easily accounted for by an intelligent reader, according to the theory laid down in this paper.

Of Glauber salt.

Of oxygenated muriatic acid.

On steeping in this liquid.

We were somewhat astonished that those seeds, viz. wheat, rye, barley and oats, which had been steeped in the abovementioned oxygenated muriatic liquid, even during 48 hours, did thrive admirably well; whereas the same seeds steeped during so long a time in some of the other medicated liquids, were much hurt, or had lost their vegetative power. The same oxygenated liquid poured upon the ground had also a beneficial effect.

No. IV.

ESSAY ON MANURES.

Submitted to the Consideration of the Board of Agriculture.

By JAMES HEADRICK.

By *Manures* we mean all substances which, being added to the soil, render it more fertile or more productive of plants.

At what time, and by whom, the various manures at present in use, were first discovered and applied, cannot now be ascertained. Their history is concealed in remote antiquity, and historians have been so much occupied in the detail of disastrous events, that they have seldom had leisure to record those which have proved most beneficial to mankind. When agriculture was first introduced, there was probably little occasion for solicitude in collecting substances which might restore the exhausted fertility of the earth. Before the appropriation of land, men would naturally select such spots for cultivation, as appeared most likely to yield a suitable return; and when these were exhausted by cropping, they would rather advance to new land, than think of repairing the old. To this cause we may ascribe the rapid destruction of ancient forests, which accompanied the progress of agriculture in most parts of Europe.

America is nearly in a similar situation; there they find it more profitable to clear new land, than to manure the old. The long accumulation of leaves and other vegetable matters in the woods, may be considered as a manure already provided by nature. Every time such earth is stirred and exposed to the air, a new fermentation is excited; and it continues to yield abundant crops until its fermentive power is exhausted. It is only in consequence of the demand excited by the extension of towns, or convenience for exportation, that men are induced to cultivate the land by the application of manures.

But in a country like Britain, where every spot is appropriated, and where the multiplication of the means of subsistence is so important, no object is of such general concern as the collection and proper application of manures. Every one ought to assist, either by his labour or advice, to increase the general aggregate; yet we are sorry to remark, that this, like many other things which are every body's business, is seldom so much attended to as its importance deserves.

For the sake of perspicuity, we propose to divide this chapter into the following sections.

Sect. I. Shall contain an enumeration of the various substances now used as manures; specify the modes by which they are most generally applied; and suggest what may appear to us improvements.

Sect. II. Shall contain a few remarks upon the effects of manures upon the soil.
Sect. III. Their effects in the production of plants.

SECTION I.

Enumeration of the various Substances used as Manures.

Manures are derived from the three kingdoms of nature,—the animal, the mineral, and the vegetable: or they are compounded of two, or all of these kinds. Although we do not mean to follow this division very closely, yet it is proper, for the sake of arrangement, we should keep it in view.

Of Dung.

The dung of all animals makes an excellent manure, and is probably the first species whose efficacy would be discovered. Dung primarily consists of the feculent matter left in the alimentary duct, after the absorbent vessels have carried off those parts which are adapted for the sustenance of the body. In its progress through the intestines it receives the bilious juice, and is perpetually lubricated by mucilaginous matter exhaled from the intestines; by which the feculent matter of the food is animalized, that is, impregnated with matter which had formed part of an animal body. This mucilaginous matter is soluble in water. When extended to a certain degree by water, it is extremely apt to putrefy, and yields in consequence of this volatile alkali, though this salt does not exist in it while fresh. This mucilage exists also in vegetables, though in a less concentrated form.—There are two species of it; one that dissolves both in hot and cold water, which may be distinguished by the name of gelly, or animal glue. To this gum, and the paste made from flour, seem to correspond, in the vegetable kingdom.—The other species dissolves in cold, but coagulates in hot water. Of this the serum of the blood, and whites of eggs are examples. M. de Fourcroy * discovered in plants a matter similar to these, which he calls *albumen*. It is soluble in cold, but coagulates in hot water. He found this substance yielded volatile alkali, either while it existed in the living plant, or while exposed to putrefaction, to which its tendency is rapid. Acids render it gelatinous, and cause it to resemble the former species.

Besides these principles, the feces of animals are impregnated with a portion of oil, with the phosphoric acid, either free or combined with soda, or other bases.—But the original salts of the feces it is unnecessary to discuss particularly, as they are of much inferior importance to those which are formed during the process of putrefaction.

Urine

Appears to be a more perfect extract from the animal system than the other. All the elements which enter into the composition of the animal body seem to be combined in it. Our surprise must therefore be excited, that this valuable substance should be so much neglected; that so little care should be taken to mix it with the dunghill, or to putrefy and carry it to the field by itself.

Flesh

Is a powerful manure, if properly applied. It is common to throw cattle and horses, when they die of disease, out to the fields to be devoured by dogs; to the

* Annales de Chimie, vol. III. p. 252.

great annoyance of the neighbourhood, from the pestilential vapours which they emit. The dogs too, being gorged with putrid flesh, are in great hazard of the canine madness. Such carcasses should be cut into small pieces, their bones broken here and there, and mixed into a great mound of earth or rubbish. Lime might be added to hasten the putrefaction. The skeletons of horses which are commonly thrown from dog-kennels, should be treated in this manner. Even bones that are thrown from the kitchen might be accumulated in a mound of earth; as such bones still contain a large proportion of mucilaginous and cartilaginous matter, which is the chief subject of putrefaction. After such earth has remained a sufficient time, and has been properly turned, the bones may be picked out, and the remainder will be a powerful manure, being impregnated with the putrid effluvia of the bones.

In fishing towns, the bones and refuse of fish should be carefully collected, and mixed with earth. These substances are too powerful of themselves; but when properly mixed and putrefied, make excellent manure.

Among the principles of animal manures, we forbear to enumerate oils,—which are so much resorted to, and make such a mighty figure in theories concerning the food of plants. Oils seem not to differ much from mucilages, except in the proportion of their component elements *. The fat oils of animals and vegetables always exist in combination with mucilage. From this they derive their tendency to putrefaction: deprived of this, they are hardly capable of this process; and we shall see that no animal or vegetable matter whatever is of any use as a manure, until it has undergone a certain degree, at least, of the putrid fermentation.

The dung of some animals is more perfectly animalized than that of others. This is partly owing to the quality of their food, partly to the structure of the animal. Fowls, which feed mostly upon seeds, and whose stomachs, by their great muscular force, assisted by stones which they swallow, serve the purpose of teeth to produce a perfect mastication, emit, of course, feces very strongly animalized. Ruminating animals generally emit more powerful dung than those which do not ruminate, provided their food be the same. Thus the dung of sheep and oxen is stronger than that of horses; because the latter do not so completely masticate their food as the former. Human excrement, and that of swine, is stronger than the last, both from the quality of their food, and its more complete digestion.

Hence the propriety of carefully mixing the various species of excrement in the composition of dunghills; that the deficiency of animal matter in one, may be compensated by its excess in another.

Of Putrefaction.

We have already observed that no animal or vegetable matter contributes to the fertility of land, until it has undergone some degree of the putrid fermentation. Of this any person may be sensible who remarks the spot where an animal has been slaughtered, or its blood poured out. All vegetation is for a time suspended, and the place may sometimes remain sterile for years. A quantity of raw dung will produce the same effect, and the spot does not recover its fertility until the manure has time to rot. Turning up the earth to the air will hasten the return of the fertility, by accelerating the putrefaction.

* For M. Lavoisier's analysis of olive oil, see Chaptal's Chemistry, vol. III. p. 51,—translated by Nicholson.—One pound of olive oil is stated to contain of

Coal, or carbon,	12 ounces	5 gros	5 grains
Hydrogen -	3 ——	2 ——	67 ——

There are three kinds of fermentation distinguished by the products which they yield; the *vinous*, *acetous*, and *putrefactive*. The first can only take place in bodies that contain sugar, and are distended by a sufficient quantity of water. The second may take place in all bodies that contain a sacharine or mucilaginous extract. The last is common to all bodies, animal or vegetable, which either are, or have been organized. These fermentations are commonly supposed to succeed each other in a regular order. But the same body may be made to commence either with one or other, according to the circumstances in which it is placed *.

Perhaps the term *fermentation* may be used in a more general sense to denote every process by which the component elements of bodies undergo a change of arrangement, and are presented under new combinations. In this sense we shall have occasion to apply the term, not only to the change produced upon manures by putrefaction, but also to the changes which these manures produce upon the soil.

Without entering into a detail of the various processes of fermentation, it is surely of importance to mark the phenomena attending putrefaction. It is only of late that any thing satisfactory has been offered on these subjects; and, indeed, before the improvements which have been made in pneumatic chemistry, mankind were not in a condition to form any opinion concerning them.—Although many experiments remain yet to be made to enable us to judge accurately concerning putrefaction, yet a few hints have been obtained, which may be of great practical utility in the preparation of manures.

This process seems in all respects the same with inflammation, though it advances in a much more slow and gradual manner. Hence products which would be dissipated by the violence of inflammation, are retained and modified in the more gentle process of putrefaction. Like inflammation, the process we treat of, is frequently attended with an emission of light; as is verified in putrid fish, and several kinds of flesh. The putrid leaves of trees, rotten wood, moss, &c. when moist, if they are turned over and exposed to the air in a dark night, appear luminous.

Now air is necessary to inflammation, and must also be necessary to putrefaction. Some bodies will indeed putrefy in situations where they are excluded from the admission of air; but the process is very slow, and the air necessary seems to be derived from the decomposition of the water which they contain. Nor is it proper that the air should be too rapidly changed, as this is attended with an exhalation of the putrefying matter.

Water is also necessary to putrefaction; for dried animal and vegetable substances never putrefy. But it is highly improper that water should circulate through the putrefying mass, or that it should be immersed in this fluid.—In the first case, the mucilage, which we have already represented as the very essence of the putrefying matter, is extracted.—In the last, the mass is too much chilled, and excluded from

* That milk is capable of the vinous fermentation appears from the thoumiss, which the Tartars make from mares' milk. (For an account of which, see Memoirs of the Royal Society of Edinburgh, vol. . p.). I have somewhere seen it observed, but do not recollect my authority, that the ancient Caledonians knew the art of fermenting cows' or goats' milk, into a vinous liquor. They used a particular ferment, probably the sediment of liquor already fermented. In place of hops, they used a decoction of heath, to prevent the liquor from running into acid.—It would certainly be an object to attempt the recovery of such an art, as the whey, if kept sweet, would answer equally well, or better than the milk; and might hence become valuable.—Most of the sugar of milk is extracted in the whey.

the action of air. Hence a dunghill should have no more water than it is disposed to retain, like a sponge, within its pores. The water seems to perform the office of a solvent, by which the different ingredients are brought to act upon each other; and it seems also, by its decomposition, to supply a considerable addition to the manure.

Heat is also necessary to putrefaction; but there is no occasion to be solicitous about this article, as the putrefying body, if in sufficient quantity, soon generates a considerable degree of heat of itself. In this the putrefactive process is analogous to inflammation, and it proves that the putrefying body is absorbing a portion of oxygen, or pure air.

This may perhaps be more generally stated—That when bodies pass from a more rare, to a more dense combination, they give out a portion of their latent heat. Wet straw, hay, rags, &c. which contain much air within their pores, have been known to take fire by putrefaction. Such accidents might frequently be expected in dunghills, were it not for the mixture of animal matter with the straw. The former, though much more disposed to putrefy than the latter, does not so readily admit the air into its interior recesses. Hence it checks the rapid putrefaction of the straw; while this, by its great porosity, and ready admission of air, accelerates the putrefaction of the former.

From these premises we may deduce a few practical rules, which may be of use in the management and construction of dunghills.

1. Excrements of different species should be mixed. Horse-dung is too open for slow fermentation; it consists of an infinite quantity of small particles of hay or straw, with only a small proportion of animal matter. Hence it ferments too rapidly, and raises a heat so great as sometimes to dissipate part of the fermentable matter. Cow-dung, again, is so viscid that it is not easily penetrated by the air; its fermentation is therefore too languid. When mixed, they correct each other. If this cannot be done, dry horse-dung should be saturated with such additions of water, or urine, as may help to close its pores.

The thermometer might be used as a test of the proper fermentation of dung. When this is too rapid, it raises a heat approaching to inflammation, which wastes the useful parts, leaving a product somewhat similar to ashes.—When this happens, farmers say the dung is *scalded*, or *fired*.

2. Great care should be used to have the dung completely saturated with straw, or other vegetable matters. In many parts of England they grub up their stubble, or cut it with a scythe, to litter their cattle, or mix it with the dung in the yard. In Scotland they generally cut the corn so close, that very little is left behind. The latter is certainly the best practice; for it is easier to gather in all the straw by one operation, than by two.—Where straw is wanting, ferns make an excellent addition to the dunghill: rushes too, and weeds before they run to seed, may be employed with advantage; even the tender shoots of broom may be gathered for this purpose. If still the dung remain unsaturated, dried moss is an excellent addition. We say dried, for without this precaution it cannot be made sufficiently to imbibe the animal juices, unless made into compost, which had better be done in the field. We do not approve of covering a dunghill with earth, unless it be the rubbish of old houses: earth compresses it too much, and excludes it from the air. It is better to carry the dung to the earth, than the earth to the dung. The only exception to this rule is, when a dunghill is sufficiently fermented, and it is not needed for immediate use. Should this case occur, a coat of earth, about a foot in depth, prevents the waste of

the fetid vapours, and preserves the dung in a proper state for use. It may be planted with cauliflower, or cabbages.

Vegetable substances keep the dunghill open and porous, for the admission of air; and being saturated with the animal juices, they ferment so slowly as not to waste their substance, and yield a large addition of manure. It is common to throw down all the ashes in one part of the dunghill, where they never mix with the other parts. This evil should be corrected, by spreading the ashes regularly over every part; they would thus absorb the juice, and promote its fermentation. Ashes, impregnated with animal juices, form the very best species of manure. At foundries, glass-works, and other manufactories, incredible quantities of manure might be procured, by selecting the finest of the ashes, and directing upon them all the urine and excrement dropped at these works.

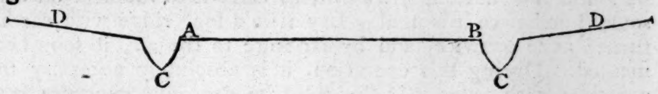
No practice can be more barbarous, than throwing the seeds of weeds which have been cleaned from the corn, or weeds loaded with ripe seeds, into the dunghill. Seeds of all kinds, while the skin remains unbroken, possess a power of resisting putrefaction; they are even capable of resisting the dissolving power of the gastric juice in the stomach, which melts the hardest bones. Such practice occasions a perpetual multiplication of weeds, in a ratio that exceeds calculation: we are not certain if it is even safe to allow the fowls to eat them; for a part will pass through unbroken, and vegetate where they are dropped.

3. With respect to the best situation of a dung-yard, we shall proceed to offer our ideas, agreeably to the foregoing principles.—It should be seated on a clay, or rocky bottom, with a northern aspect, and be sheltered from sun and wind. A clay, or rocky bottom is necessary to prevent the juices from sinking into the earth; and where this is wanting, it is worth while to lay an artificial stratum of clay and pavement below it.

We approve of a northern aspect, not for the reason commonly alleged, that the north wind is loaded with nitre. No man ever saw nitre floating in the air, or could collect it from this element. The atmosphere indeed contains the principles of the nitrous acid; yet these principles are not disposed to combine (as we shall have occasion to mention), except when they discharge their office in the process of putrefaction. Our reason for preferring a northern aspect is, that the sun's heat is apt to exhale the most valuable part of the juices, and there is no occasion for any additional heat above what is generated by the putrefaction itself. Hence, in warm climates, we conceive the putrefaction of dung should be conducted in pits or caverns under ground.—For the same reason it may be proper to inclose the dung-yard with trees. High winds exhale the juices, and the same evil arises from the too frequent shifting of the air, which we stated as a consequence of the frequent shifting of the watery fluid. A part of the air, as well as water, is decomposed in the putrefying mass, and it readily absorbs from a stagnant atmosphere, that portion of air which is necessary to continue the process.

Those who have treated this subject, are much divided respecting the most advantageous construction of a dung-stead. Some recommend a declivity, upon this principle, that it admits the air more readily, and hastens the putrefaction. But they do not advert that it also allows the whole essence of the dung to be washed out by rains. Others recommend a deep hollow, for retaining the moisture. But by this construction, the essence is washed to the bottom, where it never ferments, being too much soaked with water; while the upper parts may be scalded by excessive fermentation, and defect of moisture.

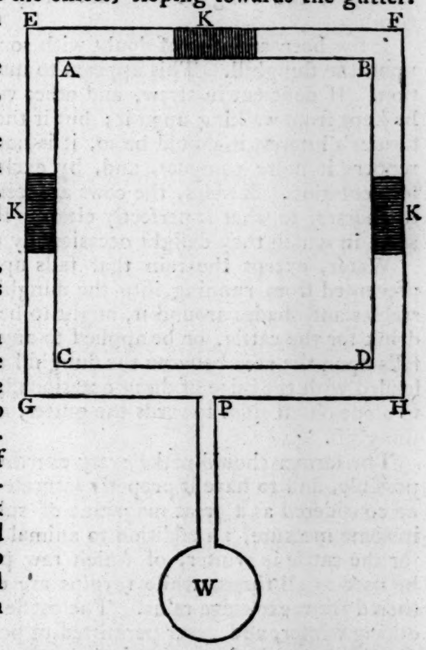
Agreeable to the principles already stated, we would recommend a construction that combines the advantages of both these constructions, without partaking their disadvantages. We would have the dung placed upon a level platform, elevated a few inches above the gutter which surrounds it.



AB is a section of the platform causeyed with stones, or laid with flags.

CC the gutter around the platform.

DD the space between the dungstead and the offices, sloping towards the gutter.



ABCD is the area, or base of the platform on which the dung is laid.

EFGH the gutter which surrounds the the platform. It may be 8 or 10 inches deep, and may slope on both sides.

KKK roads across the gutter into the dungstead, opposite to the door of each office-house. These should be open below, to allow the juice in the gutter to flow all round.

W a well, into which the superfluous juice, which cannot be retained in the gutter, flows through the conduit WP.

P the opening into this conduit; which should be at such an elevation as to cause the water to cover the whole surface of the dungstead with a very thin sheet. This to prevent the bottom of the dung from becoming dry. We have thrown this well out of the dung-yard; but if it be covered to prevent cattle from falling in, it may be sunk at P.—This well should be occasionally filled with straw, ashes, or dried moss, to absorb the juice, which being occasionally removed to the dunghill, will yield a large proportion of excellent manure.

All the urine from the stables and cow-houses, soapy suds, chamber ley, and foul water from the kitchen, should be conducted, by subterraneous drains, to the gutter, and occasionally thrown upon the dunghill by scoops.

Thus the dunghill will be impregnated with as much animalized matter as it can hold, and will not be obliged to retain any more water than the putrefaction requires. What is washed out by excessive rains, being collected in the well, is soon restored back, with an addition of vegetable substance sufficient to retain it.

Above all things, let me repeat—Suffer not a particle of urine, or of water that has passed through the dunghill, to escape; for they are the very essence of the manure. If they cannot be saturated with vegetable or other substances, let them be made to flow over some contiguous field. They will soon exhibit effects which far surpass the power of ordinary dung.

The dunghill should be turned once or twice, if necessary, to mix the parts that are most fermented, with those that are least. If found too dry, it should be watered with the juice that has drained from it, or with common water. If after all it be found not sufficiently fermented, carry it to the field on which it is to be laid, some time before it is used. Lay it in a long ridge with earth over it. It may be turned once or twice, and by exposure to the air, it soon becomes completely fermented. During this operation, it is absolutely necessary to have the dung well saturated with water. If this fluid be deficient, exposure to the air either dries it, and stops putrefaction, or excites such a heat as fires and wastes its substance. If, therefore, the dung be not sufficiently soaked, water should be added during the turning.

It has been a matter of doubt with some, whether cattle should be allowed to tread upon the dunghill. This appears to me to depend upon the nature of its composition. If deficient in straw, and other vegetable substances, they ought certainly to be kept from walking upon it; but if the straw be in proper quantity, and it is every farmer's interest it should be so, it is not the worse of compression by cattle. This renders it more compact, and, by excluding excess of air, prevents the too rapid fermentation. Besides, the cows are seen to prefer the hay or straw that has littered the horses, to what is perfectly clean. Hence the dunghill is to them a kind of desert, in which they delight occasionally to indulge.

Water, except the rain that falls upon the space which it occupies, should be prevented from running into the dunghill; even what flows from the roofs of the stables and shades around it, ought to be conducted away by roans. It may serve as drink for the cattle, or be applied to any other purpose. We except the water that falls upon the area between the dunghill and the stables and shades; this is generally loaded with the juice of dung occasionally dropped there. The area ought therefore to slope on all sides towards the gutter, and the water it collects be thrown upon the dunghill.

The farmer should make every exertion to accumulate as much animal dung as possible, and to have it properly saturated with vegetable matter. The dunghill may be considered as a great magazine of subsistence; and every addition it receives, is, in some measure, an addition to animal existence. Green crops should be provided for the cattle in winter, of which raw potatoes possess many advantages; they can be used at all times, while turnips are either locked up by frost, or cannot be gathered from excessive rains. The cattle ought to be kept wholly in the dung-yard during winter, and never permitted to poach dressed pasture, especially if it consists of clay; even during summer, it is advantageous to have the farm so arranged, that the cattle can return when they please from their pasture, and either rest in a shade, or eat clover, or cut grass, provided for them in the dung-yard. By these means a great accumulation of dung will be procured, and the farmer be enabled to increase the fertility of his land.

Effects of Putrefaction.

We may distinguish three stages in the putrid fermentation:—The first, when the heat is greatest, and the body is most disposed to emit volatile products; among which the volatile alkali may be discriminated by its sharp urinous smell, and causing the eyes to water.

The second period is of longer duration:—The heat gradually diminishes, the straw becomes very brittle, fixed salts are developed in the mass, and the whole be-

comes much more dry, pulpy, and compact than formerly. When this second stage is completed, the manure is ready for use.

If the putrefaction be much longer continued, vegetables lose their organic texture. The whole matter is resolved into a dry black earth, known by the name of vegetable mould. Though this earth be the most excellent of all passive bodies in which plants can fix their roots, yet it does not possess that degree of activity for their production, which the manure, from its continued fermentation, can exert. The time required to ferment a large quantity of dung into a *caput mortuum* is much longer than is necessary to ferment raw dung into manure; and it requires to be often turned up to the air. But the inference we would draw from the premises, is, that dung should be applied immediately after the second stage of the fermentation is completed, and while the earthy fermentation (if we may be allowed the expression) is yet to commence.

The phenomena attending this, as well as many other common processes of nature, have not yet been marked with that attention which their importance deserves. The various circumstances connected with the several steps of its progress; the aërial, as well as fixed products which it developes, have not yet been accurately ascertained; we shall therefore endeavour to enumerate those few facts that have been observed, without pretending to offer any thing satisfactory.

The putrid fermentation produces a complete change of arrangement in the component elements of the original body. Compounds which formerly existed in the body are dissolved, and new compounds are formed which did not formerly exist.

Towards the commencement of the process, gases are emitted, which Chaptal* states to be nitrogen, hydrogen, and carbonic acid. The two last seem to arise from the decomposition of water by means of the carbonic matter in the putrescent mass; the first seems to flow from the decomposition of the mucilage. Along with these there is evidently a part of the putrid matter carried off unchanged, which increases the offensive smell.

The ammoniacal gas, or volatile alkali, is also evolved, as we already remarked. This is now known to be a compound of the nitrogenous and hydrogenous gases, and seems to arise from the decomposition of water by the mucilaginous parts of the body. The mucilage supplies the nitrogen, the water the hydrogen, which at the instant of the mutual decomposition of these ingredients unite, forming the volatile alkali.

The fixed products which are found to consist of the vegetable earth already described, mixed with a portion of charcoal. This is in all respects similar to the earth which vegetables and animals yield, when burnt with fire. Whether it be a product of chemistry, or existed in the original bodies, we shall not pretend to determine; but we never heard of its being extracted from these bodies without the aid of putrefaction, or of inflammation.

Oil, salts of various kinds, both simple and compound, are also found. But the most remarkable salt is nitre, which is now found to exist, though no trace of any of its constituent parts could be discovered in the original matter before putrefaction commenced. It seems chiefly to form towards the last stage of the putrefaction, when the body begins to resolve itself into earth.

The author has frequently collected portions of this salt from dung that had been laid out in heaps upon fields, after a tract of dry weather in spring. When the dung

* Vol. III. p. 276.

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is turned over, it soon forms, like shining hoar-frost, upon the surface. A portion being dissolved in water, a paper dipped into the solution burns like a match, which is a certain test of the nature of the salt; it cannot be collected after rains, as these wash it into the earth. He has no doubt but it can be manufactured in this country with advantage.

The theory of its formation is as follows: The oxygen of the atmosphere combines with the nitrogen emitted from the mucilaginous part of the putrid mass, forming the nitrous acid. At the same instant, vegetable alkali, a body with whose composition we are unacquainted, being evolved, combines with the acid, producing the salt of nitre. The oxygen, by entering into composition, deposites its heat, which raises the temperature of the fermenting body. A greater quantity of nitre is produced, and more rapidly, by mixing the dung with earth and old lime. The last hastens the putrefaction, promotes the union of the constituent principles of the nitrous acid; and serves as a basis to which the acid may attach itself. But the salt formed with lime is nitre of lime, and must be decomposed by means of wood ashes, in order to obtain the common nitre. I conceive it would be an improvement to mix the compost with wood ashes in the first instance, and am disposed to imagine that this is the improvement so much extolled lately in France.

Many other products are formed in putrid matter, which it is unnecessary to enumerate here, as they have not been fully investigated. We shall only state that sulphur, iron, manganese, gold, and various metals, are found in the residue of a long continued putrefaction.

Having thus endeavoured to penetrate the arcana of nature, let us attempt to emerge into the region of practical utility.

Farmers cannot be at too much pains to carry to the dunghill all putrescent matter which is scattered about the steading. This gives their residence a clean husband-like appearance: cleanliness, by promoting health and comfort, is a great incentive to industry; while the habit of wallowing amidst filth is both a mark of laziness, and tends to increase the disposition from which it arose. All rubbish from the stack-yard ought to be collected, and either used as litter for the cattle, or mixed with the dung; by allowing it to remain upon the surface, as is frequently done, it converts the yard into a bog by the time the ensuing crop comes to be put in. Wheat straw answers best of any for littering the cattle, and mixing with the dung; as it is strong in the reed, and contains much air within its substance. Except for thatch, it is fit for no other purpose, as unless it be previously cut by a machine the cattle are not fond of eating it. Peas and bean straw are also well adapted for the composition of a dunghill, as they contain much fermentable mucilage. But the latter ought to be well mixed with the dung, and kept moist, as from its extreme openness, it is apt to dry, and fire. Every patch of dung that is dropped accidentally around the farm offices, should be carefully collected, and mixed with the heap. If allowed to remain detached, such patches either become dry and do not rot at all, or, from want of a sufficient quantity to generate heat, and retain moisture, they gradually moulder into earth, without passing through the putrid fermentation which produces manure. From this we may see why bare pasture does not so much improve by the tath of cattle, as that which is kept rank by understocking. The tath of cattle, dropped among rank grass, meets with withered vegetables, with which it can mix; it is kept moist by the grass which grows over it, and by fermentation conveys all its manure into the soil.

Other Animal Manures.

The raspings of horns make excellent manure; they contain a large proportion of fermentable animal mucilage, united with the fibrous part of the horn, in which charcoal predominates. They should be laid in heaps, exposed to moisture, and allowed to ferment; during this process they emit a large quantity of volatile alkali, which, from being formerly distilled chiefly from shavings of hartshorn, was long known by the name of spirit of hartshorn. If the shavings of horn be not sufficiently fermented, laying them on the surface of land some time before they are harrowed in, produces this effect. As they contain a large proportion of mucilaginous and oily matter, a small quantity produces a great effect: but this manure is only to be procured where there are manufactures which make use of horn.

Hair and wool also operate as powerful manures. They are composed of nearly the same ingredients as the former. The most economical way of using these substances is, either to spread them in a thin stratum over the surface of land, some time before it is wrought, or mix them in composts with earth. Woollen rags, spread upon the surface of land, soon produce great fertility; or they may be made to raise excellent potatoes, by wrapping the sets in rags when they are planted: but in this case, they should be moistened with water to hasten the putrefaction.—The hairy and useless parts of wool should be carefully collected at sheep-shearings, and applied as manure.

Tanners' bark, if properly mixed with hair and refuse of leather, is an excellent manure. From the acid of galls, or astringent principle, with which the bark is impregnated, it is disposed to ferment very slowly; and it requires a large impregnation of animal fermentable matter to operate this effect in its fullest extent. It is hence chiefly used in hot-beds, to correct the too rapid fermentation of horse-dung. The latter, by itself, ferments with a rapidity approaching to burning; it therefore raises too great a heat, which is not sufficiently permanent: this evil is corrected by a proper mixture of tanners' bark, and very often the bark itself is used without any addition of dung. If this substance be applied to land, it ought to be harrowed in with the seed, in order that contact of air may complete its putrefaction; or it may be mixed in a compost with earth, and a considerable proportion of horse-dung and lime, to produce a complete fermentation. The galic acid, when strongly impelled by a sufficient mixture of animal fermentable matter, is either decomposed, or is absorbed by lime and the alkalies produced in the fermenting mass: hence it can no longer impede the vegetation of plants.

Dung of fowls is a very powerful manure; but is too acrid to be used in very large quantities: its nature and qualities have not yet been properly investigated. In some rocky islands of the Western Hebrides, which are resorted to by solan geese, and other sea-fowls, I am told it is accumulated in such quantities that ships may be loaded with it. The dung of animals which subsist wholly upon fish, must be extremely powerful, and if in sufficient quantity, might become a very lucrative subject of commerce. The best way of applying the dung of fowls is, to mix it up in heaps with powdered quick lime; which dries, and causes it to crumble into dust. It may then be sown on the field by the hand; or it may be distended in a compost by earth or moss.

Calcareous Manures.

Calcareous earth, or lime, is a substance which exists throughout nature in an immense variety of forms. However inexplicable it may appear, lime, in all its

forms, seems evidently to have been derived from sea-shells. Many strata of limestone and marble are wholly composed of an immense mass of shells cemented together. Those beds, such as chalk, Italian marble, and others which exhibit no marks of shells, seem to have been formed by deposition from water, or some other menstruum, which had decomposed a bed of shells, and conveyed the lime to the places where it is now found.

When lime is completely freed from water, and the carbonic acid, which generally adhere to it, we commonly distinguish it by the name of quick lime. It then possesses all the qualities of an alkaline salt; is soluble in 680 times its weight of water; it resembles caustic alkalies in its acrid and urinous taste; and, like them, powerfully corrodes animal and vegetable substances.—It ought, in fact, to be esteemed a simple salt of an alkaline nature.

But this substance is seldom presented to us in this state; it most generally occurs in the form of a neutral salt; and the carbonic acid is the one with which it is most commonly neutralized. The generic chemical term for it in this state is, *carbonate of lime*, denoting a combination of carbonic acid with lime; or it is commonly called *crude* or *raw* lime, which is subdivided into a variety of species, the most prevailing of which are marble, limestone, chalk, marl, petrefactions, crystals, or spar of lime.

We may hence perceive the difference between quick lime and crude lime:—The first, being a simple salt, has a strong tendency to combination. It therefore strongly corrodes animal and vegetable substances, because it absorbs the moisture, the oil, and carbonic acid which they contain; it operates upon them in a way similar to inflammation. But it is a powerful antiseptic, that is, prevents the putrefactive fermentation in those bodies which it is not adapted to decompose. For example, it preserves water free from putrefaction, for any length of time. Crude lime again has no corrosive power; but it strongly impels the putrefactive fermentation in all animal and vegetable substances, deprived of life, with which it is united. It hence follows that in so far as the effect of lime as a manure depends upon exciting putrefaction in the animal and vegetable substances, contained in a soil, it can only begin to operate in this way after it has reabsorbed from the atmosphere that portion of carbonic acid which it lost by burning. The two processes are in fact the same; except that in the first case the lime appropriates to itself those principles of which it had robbed the body on which it acts; in the last it gently promotes their decomposition, and causes their principles to mix with the soil.

A certain proportion of the carbonic acid added to lime renders it absolutely insoluble in water; but an additional quantity of the same acid renders the lime again soluble. The lime being gradually deposited from this compound by the slow evaporation of the water, and its excess of carbonic acid, forms crystals. Hence crystals of lime are the purest state in which this substance is presented by nature, as they contain no extraneous matter, except the water of crystallization, carbonic acid, and lime. We may therefore assume this as the standard to which we may refer the purity of all other species of lime, in its natural state.

Water and carbonic acid are common to all the states of crude lime; but the other species we have mentioned contain also a greater or lesser proportion of sand, or clay, or both. Hence equal quantities of the others do not contain equal weights of the pure calcareous earth, on which their property, as manures, chiefly depends. Some limestones are so full of sand that it is difficult to burn them without melting the stone into a slag; and such lime makes mortar without any addition of sand. Others

contain so much clay, that they require to be slacked while they are yet red hot, and while their pores are laid open by heat, for the admission of water. The proportions of clay and sand, from these extremes, to the purest or crystallized state of the calcareous stone, are infinite, and vary even in the same stratum. The medium proportion of most strata I have examined is, from 70 to 80 parts in 100 of crude lime; the rest of the earthy part is either clay or sand, or a mixture of both. Many limestones wrought in Scotland are much poorer than these.

Dr. Black was the first person who discovered these properties of lime. Inquiries on this subject have also been made by Bergman, Kirwan, and other chemists. It has been ascertained that crude lime, in its ordinary state, and when divested of every extraneous mixture of other matter, contains in 100 parts—

Water of composition	-	11	parts,
Carbonic acid	- -	34	——
Pure, or quick lime	-	55	——

Therefore a mass of limestone, in which there are 80 parts in 100 of crude lime, contains in reality no more than 44 parts of pure lime. After such a stone is burnt, it has lost 27.2 parts out of 80, the amount of the crude lime in carbonic acid, and 8.8 of water; which are expelled by the fire. Hence, if we knew the quantity of crude lime contained in a calcareous mass, it is easy to calculate the quantity of pure or quick lime it will yield by burning.—On the other hand, if we know the quantity of quick lime, we can calculate the weight it will regain by slacking, and exposure to the air. Hence, also, it is most advantageous to carry home lime immediately after it is burnt; especially if the distance be great.

Besides the sand and clay already mentioned, marble and limestone generally contain a mixture of petroleum, or rock oil, the same that is found in coal-tar. Sometimes also they contain sulphur and iron, or other metals. The petroleum gives a blue or black colour to the stone; but evaporates by burning, and the product is white. When the iron abounds, the stone becomes rusty by exposure to the air; and if in great quantity, the burnt lime is often red, like brick-dust: I have also discovered traces of magnesian earth in certain limestones.

The same observations are applicable to marl of every species; therefore colour is a very fallacious mode of ascertaining whether a body be of a calcareous nature, and applicable as a manure. Some opinion may indeed be formed from the texture of a stone; but even this is liable to much deception, and persons often expend considerable sums upon stones which have the appearance of lime; while, by adopting a proper method, they might have been undeceived at the expence of a few halfpence.

We conceive it therefore a benefit done to agriculture to digress a little, and point out a few simple methods by which any person, of ordinary understanding, may satisfy himself, not only whether a particular substance contains lime, but also the exact proportion which the lime bears to the mass. Every person may thus ascertain the precise value of a subject of this nature, before he proceeds to advance expence in working it.

Analysis of calcareous Bodies.

Some opinion may be formed of the species of earth with which a calcareous body is alloyed, from the appearance of its fracture: if it breaks with a smooth glutinous surface, and if a nail, or point of a knife, drawn across it, makes a smooth rut, it is probably alloyed with clay: if, on the contrary, its fracture be uneven, and small shining particles appear in it; if a nail meets with resistance in crossing it, the alloy is probably sand.

The proportion of pure lime which a calcareous body contains may be found either by fire, or by acids.

By Fire.

Suppose a pound, or any known weight of the body in question, be well burnt in a kitchen fire, and after it is burnt, the loss of weight it has sustained, be ascertained: this loss consists chiefly of water, and carbonic acid. Therefore the quantity of pure lime in the mass may be deduced from the proportion stated in the above table, by the Rule of Three.

But this process is not accurate; for if the body contain sulphur and petroleum, these will evaporate in the burning, and cause the calculation to exhibit a greater proportion of lime than really exists.

By Acids.

It is well known that lime is soluble in most of the acids; therefore if a strong acid be added to it, the carbonic acid, or fixed air, which has but a weak attraction for most bodies, will be displaced, and assume its elastic form. The carbonic acid always exists in an elastic form, except when it enters into composition with other bodies. Its escape is the cause of the effervescence, or agitation, which takes place when acids are poured upon crude lime, or mild alkalies.

Dr. Black has discovered that a certain proportion of carbonic acid always adheres to a given quantity of crude lime; and from this has deduced an easy method of ascertaining the proportion of pure lime in a calcareous mass. The proportion of carbonic acid we have already stated to be 34 parts in 100 of crude lime.

Suppose therefore you put a quantity of acid into a phial, and weigh it accurately; then take a quantity of the limestone you wish to examine, pounded and weighed, and which quantity must not exceed what the acid in the phial is able to dissolve. Add the powdered limestone to the acid, shake it occasionally until the effervescence has ceased; that is, until the whole calcareous matter be combined with the acid. During this process the matter in the phial will sustain a loss of weight, by the escape of the carbonic acid from the lime. Ascertain this loss precisely, by returning the phial back into the scale.—Suppose then you find that the limestone, by solution, had lost 20 parts in 100;—then as $34 : 100 :: 20 : 58\frac{28}{34}$, the proportion of pure lime contained in the mass.

But as this process is founded only on one ingredient in the crude lime, it is obvious that any error in making the experiment will be greatly multiplied in the result. We therefore think it may be of use to suggest other methods, leaving it to our readers to adopt one or other, as may appear most convenient.

The acids best adapted for these investigations are distilled vinegar, marine acid, nitrous acid, or aquafortis; when any of these acids is added to a body, some opinion of the proportion of calcareous matter it may contain, may be formed from the violence of the effervescence. To prevent this from becoming too violent, it is frequently necessary to add the acid in small portions, until it no longer excites agitation.

All the calcareous matter in a body is dissolved when a small addition of acid produces no farther commotion; and if the liquid be now allowed to settle, some opinion may be formed of the proportion of calcareous earth it contained, from the quantity of sediment or undissolved matter, which goes to the bottom. No particle of this sediment is calcareous; it is clay, sand, or iron, &c. with which the calcareous matter was alloyed. By deducting it therefore from the whole mass originally

operated upon, the remainder is the precise proportion of crude lime contained in that mass.

But to do this with perfect accuracy, it is necessary to pound and weigh the original material.

For this purpose such balances as are commonly employed for weighing gold may be used; but it is necessary to be more particular about the weights.

In weights which are merely intended to investigate proportions, it is of no importance to have them adjusted to any known standard. Suppose 100 be taken to represent the original mass of matter, whose component parts we wish to examine; this may be expressed by 100 coils of fine wire twisted round a cylindrical pin. If these be perpetually halved, by cutting the wire across with a knife, in a right line along the cylinder, we shall subdivide them into rings, by which we can weigh the integrant parts of the original mass: or we may subdivide them into one ring of 50 coils, 1 of 20, 1 of 10, 2 of 5, and 10 of 1 coil each; the whole making up the original sum of 100.—Any other mode of subdivision may be adopted, provided it be done with accuracy. The whole of these weights put together need not exceed an ounce, and even half an ounce may be sufficient.

The weights being thus adjusted, put the whole into one scale of the balance, and as much of the body to be examined, in powder, as will exactly counterpoise them in the other. You have therefore got 100 parts of the body, and the object is to find out what proportion of lime it contains.

Dissolve it in an acid as already directed, adding the acid in small portions, until it no longer causes effervescence; then take a filter of soft grey paper, previously weighed, and its counterpoise allowed to remain in the same scale in which the weights were placed: this filter should be placed in a glass funnel, or, if this is not at hand, a funnel of tinned plate may answer. The funnel should be inserted in a clean karaf, or wine decanter, or other glass vessel.

Into this filter throw the whole matter contained in the acid mixture, and wash out every particle of sediment along with the liquid. The liquid part is the lime combined with the acid, which will soon ooze through the filtering paper, leaving the sediment behind. Continue to pour water upon the filter until you are sure that every particle of the salt of lime is washed through.—If great nicety is required, distilled water should be used; but good spring, or rain water will cause no material error.

After the moisture has passed through, dry the filter with the sediment upon it, either in the sun or before a gentle fire. The paper being now restored to the scale, with its counterpoise in the opposite scale, the number of wire rings necessary to counterbalance the sediment upon the filter, indicates the quantity of extraneous matter with which the lime is contaminated. Suppose, for example, it takes 20 wire rings to bring the balance to a level, then in 100 parts of the stone you have 80 parts of crude lime, and 20 parts of matter which is not lime; and, by deducting the water of composition and the carbonic acid, which make part of the crude lime, according to the principles already laid down, you have only 44 parts in such a mass of quick, or absolutely pure lime.

If still you suspect an error may have been committed, and wish to attain great accuracy, you may proceed to confirm your analysis by synthesis; that is, if on restoring the lime dissolved in the acid to the sediment on the filter, you find they, added together, make up your original weight of 100, you are certain that your

process has been rightly conducted, and that your conclusion may be depended upon.

To do this, it is necessary to precipitate the lime from its acid solvent, by means of an alkali. A purified solution of pot-ash dropped into the filtered solution of lime, throws down the latter substance like a cloud. The alkali must be added in small portions, until it no longer produces a precipitation.—In this case the lime attracts from the alkali that precise portion of carbonic acid which it formerly retained in the state of stone, and imbibes from the water that portion which formerly entered into its composition. The lime is, in fact, restored to the state in which it existed in the original stone.—Every particle of this precipitate must be thrown back upon the filter, and washed by additions of water as before. You thus restore to the matter on the filter that crude lime, which was formerly withdrawn from it by the acid; and if, after being dried again as formerly, you find the weight equal to your original 100, you are absolutely certain of being in the right.

On comparing these two methods of analyzing calcareous bodies, it is obvious to remark, that the first, which proceeds upon the porportion of volatile matter in limestone, is liable to error from this cause, that the carbonic acid, during its escape, always carries off a portion of the water, or acid, in the solution. The result will therefore exhibit a greater proportion of lime than actually exists. The latter process, which investigates the proportion of fixed bodies in the limestone, is not liable to this objection; but great care should be taken to dry the products gently, and give them sufficient time. If one product be more dry than another, it is evident the results will contradict each other.

We thought it necessary to be more particular upon this subject, as we think every farmer, at least every proprietor who resides upon his estate, should keep a small phial of one of the acids we have mentioned. To ascertain whether a stone or clay be calcareous, it is only necessary to let fall a drop or two of acid upon it, and mark if an effervescence ensues: the remaining inquiries, to ascertain the value of the subject, may be prosecuted or not, according to the result of first appearances. But we hope that any person who attentively considers what is here detailed, may soon satisfy himself whether it is prudent to advance money upon any calcareous substance which may occur; and it is of vast importance that all valuable calcareous manures should be brought into action. A discovery of this kind soon changes the appearance of the surrounding district, and converts the barren heath into a fertile field.

Of Burning Lime.

The use of burning lime for manure, is merely to reduce it into small particles. As a manure, crude lime is equally effectual with quick lime, as appears from the effects of marl. Quick lime has indeed one advantage, that when it is laid on hot, and in fine powder, being soluble in water, it is easier washed into, and mixes with the soil, than can be expected in any other state. Quick lime also more effectually seizes and appropriates the moisture contained in hard clay soils, than crude lime. It thus tends more effectually to open the pores of such soils, and to render them more pervious to moisture.

We have already observed, that crude lime is merely an insoluble salt, compounded of pure lime, carbonic acid, and water of crystallization. Now burning simply expels these last ingredients by the force of heat, and thus causes the body to become more porous, and less adhesive.

It will be unnecessary to enter minutely into all the circumstances to be attended to in burning lime, as this process is generally well understood by those who practise it; we shall therefore content ourselves with a few cursory remarks.

Lime is commonly burnt either in draw-kilns, or pot-kilns: the first are most convenient for large lime-works, where there is a great consumption. The coal and lime are thrown in at the top in alternate layers, and the burnt lime (commonly called shells) is drawn out at an aperture below.—Where burning lime is only an occasional employment pot-kilns are most convenient; these are commonly sunk into the side of a hill, and faced round the sides with stone, or brick, or wrought clay: the front wall is thrown down when the kiln is cleared. When the kiln is charged, a stratum of brushwood, or peat, is laid at the bottom to communicate the flame; then a stratum of lime and coal alternately, until the kiln is raised to a high heap. In charging this kiln the largest of the stones should be placed in the centre, and so arranged as to permit the air and flame to draw through them. The smallest pieces should be placed on the sides and top; and a portion of small coal interposed between the stones and sides of the kiln. The whole is commonly covered with clay, or lime rubbish, to prevent too rapid a draught. No moisture should be allowed to stagnate in the bottoms of kilns; and to prevent springs, the bottom should be surrounded with a concealed drain.

In many cases they construct kilns with sod of great length, with apertures along the sides, to allow the air to pass into the fuel, and cover the whole with sod. Lime too is often burnt in large heaps, with or without a covering of loose earth.

The covering of pot and sod-kilns operates like a reverberatory furnace to confine and cause an equal diffusion of heat. Should an aperture break in the covering, it ought to be carefully closed; otherwise it will draw the stream of flame towards itself. The lime in this stream will be melted into slag, while the rest is only singed; the aperture below should also be stopped when a violent wind blows into it, as this will cause the kiln to be heated unequally.

Lime that contains much sand requires little fuel, and should be burned as slowly as possible. It is extremely apt to vitrify, and should hence seldom receive more than a red heat. This species is commonly called building lime, as, for this purpose, it requires little or no addition of sand. Lime alloyed with clay is not so apt to vitrify as the other, and may therefore endure a greater heat.—In all cases it may be laid down as a rule, that the greater the proportion of lime contained in a body, the more fuel, and the greater heat, is necessary to burn it. This follows clearly from the principles already laid down, that such limestone, in proportion to its richness, contains more water and carbonic acid to be expelled from it.

Lime is seldom applied as a manure, except where there is coal to burn it. A kiln of a proper construction, adapted to all kinds of fuel, would certainly be a great acquisition; as it would enable persons at a distance from coal to prepare this valuable manure by means of brushwood or peat. The Rev. Arthur Young, in his Report of Sussex, p. 34, to which I refer, has given us a plan of such a kiln. The only objections which, to me, it seems liable are, that it is difficult to construct the arches on which is reared the fabric of limestone; and that there seems to be no method of confining or modifying the heat which is once generated; so that the instant the flame below is stopped, or grows languid, the kiln is liable to be cooled by the draught of air which passes through it.

Without pretending to have reduced my ideas to practice, I shall freely submit them to the consideration of the ingenious improver; who may have command of limestone, but may be too remote from coal to convert it to use it.

Proposed Plan of a Kiln for burning Lime with every Species of Fuel.

A is the body of the furnace, shaped like an egg, resting upon its narrow end; built with firestone, or brick.

BC the side of a hill into which it is sunk.

F a fire-place furnished with ribs or branders, on which the fuel is laid, being thrown in at a small iron door; which being shut, causes a strong draught.

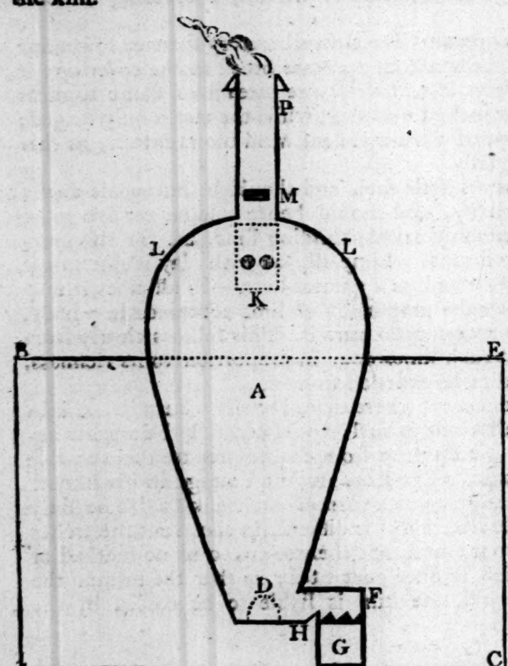
G the ash-pit below the fire.

H the aperture, or longitudinal slit, which conducts the flame into the kiln.

D an aperture, nearly equal in breadth to the bottom of the kiln, from which the lime is raked after being burnt. During the burning it must be closely stopped, either by a stone which exactly fits it, and is luted with clay: or it may be closed with bricks which are plastered with a mixture of clay and sand on the outside.

The base of the kiln should be made to slope a little towards this opening; so that when the cover is removed, the burnt lime may be easily drawn out by a long iron prong.

In charging the kiln, it may be proper to lay a few large pieces at the base, like conduits, with the hand; with a view to distribute the flame through the body of the kiln.



BE is the platform on which the stones are laid, and from which they are thrown into the kiln.—This is altogether similar to the top of a common draw-kiln.

K an aperture, from two to three feet square, through which the stones are thrown, and the kiln is thus charged. This aperture, during the operation, must be closed, either by laying a coat of clay and sand over the surface of the stones within, or by means of an iron frame, defended by a coating of fire-clay on the inside. This might occasionally be removed by a lever, and the state of the lime within inspected.

P a pipe to cause a draught.

LL a dome, arched with stone or brick, on which the pipe rests. This dome operates like a reverberating furnace, to confine and reflect the heat, so that the whole kiln may be brought to an uniform temperature.

M an aperture in the pipe to receive a damper. By the proper management of this damper, the lime

may be made to receive precisely that degree of heat which it is capable of enduring, without melting.

A kiln of this construction is calculated to produce the greatest possible effect, with the smallest possible quantity of fuel. The damper being kept open at first, soon causes such a draught as raises the whole mass of stone to the proper degree of heat. Its aperture may be afterwards so regulated as to keep the heat at this point, with a small expenditure of fuel, until the process be completed. By taking out a stone from the top, you can examine if it be fully burnt: if not, by closing the aperture, the process continues. When it is finished, the whole may be speedily raked from the lower aperture, and the kiln receive a new charge. Thus you have no occasion to waste a particle of fuel, except what is absolutely necessary to accomplish the object.

Small coal, brushwood, or peat, may be used in this kiln. Where saving of fuel is not an object, the dome and pipe may be spared, and the kiln made to work by its own draught, like any other draw-kiln. By occasionally opening the lower aperture, the lime that is ready may be drawn out, while the upper parts sink down and occupy their place. It must, however, be observed, that the want of a damper prevents you from regulating the heat in this case; and that a great part will be dissipated in the air, as takes place in a common draw-kiln.

One point only appears doubtful, and that is, whether the pipe, as we have represented it, may not draw all the heat towards itself, without allowing it to distribute over the body of the kiln. But this is easily obviated, by making the pipe as a centre to collect the draught, not from one aperture, but from a number of apertures in the dome, which communicate with the pipe by separate flues. Thus the draught, not entering the pipe in one mass, but rising from different parts in the internal surface of the dome, will effectually penetrate all parts of the limestone, and communicate an equal heat to every part.

It is unnecessary to expatiate upon the advantages which must result from a kiln of this sort, if found to answer.—All the ordinary kilns are liable to the accidents of wind and weather; and also to the accidents of receiving too much or too little fuel: these accidents are peculiarly troublesome where brushwood or peat is employed to burn lime. Sometimes the fuel singes gradually away, and never raises the proper degree of heat to produce the desired effect; at other times it goes off with a sudden blaze, vitrifies the stones on the surface, but does not last a sufficient time to affect the interior parts.—Every one knows that such accidents often happen, even where lime is burnt by means of pit-coal; and that the effect which a given quantity of fuel will produce depends much upon the state of the atmosphere, and other circumstances. But the mode we propose is wholly independent of such accidents. The kiln is so constructed that it works wholly by its own power of draught, and a given quantity of fuel will uniformly produce a given effect.—By the proper management of the damper, any degree of heat which the strongest furnace can produce, may be excited, or the body may be kept at any lower degree that is convenient, without any farther expenditure of fuel than is necessary to keep up that degree. The instant too that the effect intended is fully accomplished, the farther waste of fuel is checked. Very pure lime, which will stand an excessive heat without melting, may be burnt in a furnace of this sort, in a few hours. The heat may be varied so as to suit the poorest stone that is worth working.

If any person chooses to try this proposed mode, we would advise him to begin with a small model, which may be erected at a trifling expence. Having made himself master of its principles, he may extend his plan to any scale that is necessary.

Of Slacking Lime.

After lime is burnt, it acquires a prodigious attraction for water, which being applied to it, is seized with much avidity, enters again into the composition of the stone, and at the same time gives out its heat. Thus the sensible heat excited by slacking lime with water approaches to inflammation, and has even been known to set wood on fire. In the dark it exhibits a phosphoric light. The lime at the same time swells considerably. One remarkable fact I have observed is, that lime which is compounded with sand in the stone, swells much more in slacking than that which is compounded with clay, even though the latter should be as rich in lime as the former. The latter is also stubborn in slacking; and I have known some species of it which required to be slacked while red hot in the kiln.

Such is the strong attraction of quick lime for water, that it will slack of itself, even in a dry shade. It soon slacks by the moisture of the air, if laid in heaps in the field, but it should be carefully prevented from balling, or clotting. When ploughed down in a clotted state, especially in spongy or mossy ground, it generally becomes hard like a stone, and never after mixes with the soil. Clotting may be cured by turning the heap, and mixing the clotted surface with the parts that are imperfectly slacked: or if the whole heap be drenched throughout, it may all be again reduced to powder by mixing it with unslacked lime, and turning once or twice. In performing these operations, the parts that are not perfectly burned, and which may be known by their weight, should be carefully selected; these may be gradually accumulated in a convenient spot, and afterwards burnt in a separate kiln. Unburned stone is not more beneficial to land than so much flint.

Quick lime, like all caustic alkalies, powerfully corrodes animal and vegetable substances; yet when laid upon grass, or living vegetables, if it be soon washed down to their roots by a shower, it never afterwards attacks the living plant, however it may operate upon those that are decayed. Should men or horses be injured by it, the speediest remedy is, first to clean the part affected, then wash it with stale urine, sour milk, whey, ale, or other weak acid: these substances restore an acid to neutralize the lime, and thus render it harmless. They thus operate to prevent inflammation; but should inflammation have actually been excited to a considerable degree, it must be cured by a balsamic application.

Quick lime, exposed to the air, soon reabsorbs not only the water, but also the carbonic acid, of which the fire had deprived it; and thus returns to its original mild state, and becomes again insoluble in water. If it contain a sufficient portion of sand, or other hard particles, round which it may deposite its crystals, that is, its particles, when they pass from a state of insolubility; and if the mass be completely drenched with water, it becomes again as hard as the original stone. Upon this property its power, as a cement, depends.*

In applying lime as a manure, it is of importance to conduct this process so as to preserve the powdery state of the lime. This is best done by spreading the lime in fine powder upon the surface of the land, and keeping it in that situation until the

* Lime, as a cement, is very fully and satisfactorily treated of by Dr. Anderson in his *Essays relative to Agriculture and Rural Affairs.*

carbonic acid is reabsorbed. The lime thus recovers this ingredient in detached particles, which never afterwards coalesce. Whereas quick lime, especially if it be much alloyed with other earths, being covered down into a mossy or spongy soil, where it can satiate itself with water and carbonic acid, becomes stony, and is lost. This caution does not apply to harrowing in lime, which separates its particles, but to ploughing it instantly down, which generally throws it in masses to the bottoms of the furrows, particularly if the land be a hard ley. For such land it were better to allow the lime to remain one or more years upon the surface, before it is ploughed down.

We shall conclude this article with a survey of the various calcareous substances we have enumerated, and point out a few circumstances to be attended to, in converting them into manure.

1. *Marble.*

This substance is generally richer in lime than the common limestone; although there are limestones that take as fine a polish, and are equally rich in lime with most species of marble. The principal difference then between limestone and marble is, that limestone is full of small joints, or fractures, which are filled with marl. Though, therefore, the latter were susceptible of a high polish, yet the marl, in its fractures, by long exposure to the air, becomes soft, and the stone falls in pieces.

Marble generally lies in strata of more or less thickness. Sometimes it forms mountain rock; like limestone, it sometimes consists of a mass of shells strongly cemented: sometimes it consists of one uniform stone, of a fine grain, and of various colours. In the western Highlands of Scotland there are said to be whole mountains of marble, equal to, if not surpassing, the Parian in whiteness.* Where such stones are too remote from water carriage, to admit of being applied to other arts, it would certainly be of importance to convert them into manure.

Marble has seldom been used as a manure from the difficulty of burning it. This partly arises from the compactness of the stone, and the intimate combination of its ingredients; partly from its richness in lime. It is evident that the richer a substance is in lime, the intenser and longer continued heat is required to evaporate the water and carbonic acid it contains. From this cause, persons acquainted with the burning of limestone, have often failed in attempting to convert marble into lime.

2. *Limestone*

Is found in a great variety of forms and situations. In flat level countries, and in hills of moderate elevation, it is generally found in beds, or strata, which are similarly situated with the other contiguous strata of the earth. In these situations it is commonly connected with, or not far distant from coal. In rugged districts, where the strata are much fractured, coal and limestone are commonly found in what are called edge seams; and the limestone sometimes projects above the surface of the earth, resembling what is commonly called a dyke, or vein. In mountainous districts I have frequently met with limestone in irregular strata, imbedded in rocks; and in the Highlands of Scotland, have seen whole mountains apparently composed of this stone. It is also frequently found in detached pieces, which seem to have been worn by water. In the bottoms of many rivulets, considerable quantities of limestone blocks may be gathered; and where these appearances occur, they frequently lead to some stratum from which they have been detached by the force of torrents.

* Knox's Tour. Williams' Mineral Kingdom.

Limestone consists of all degrees of purity, from a coarse sand-stone, that will hardly stand burning, to crystals of lime, which are freest from any extraneous mixture. The poorest lime, even though alloyed chiefly with clay, is best for building, as the poorest sort requires little or no addition of sand. For manure, the poorest lime that can be burnt, is better than none; as even by the addition of the extraneous earths, with which it is alloyed, in an extremely pulverized state, the soil is improved.

From the principles already laid down, every one may see that it is more economical to burn lime where it is found, and carry the shells, or burnt lime, to the farm. For, supposing the stone to be perfectly free of any extraneous alloy, it will lose 45 parts in 100 by effectual burning; that is, 100 tons will be reduced to 55 in weight, by the expulsion of its water and carbonic acid. Hence also the purest lime ought to be preferred, if the distance be considerable; because the extraneous earths in lime suffer no change in burning: they increase the weight, without adding much to the value. And hence lime ought to be carted immediately after it is burnt, before it begins to reabsorb its water and carbonic acid.

3. *Chalk*

Is no where found in Scotland, nor in the contiguous counties of England, so far as we know. It abounds much in many districts of England farther to the south. The subsoil of many large tracts is wholly composed of chalk; and sometimes the upper soil is too strongly impregnated with this substance. New additions of calcareous earth are therefore no improvement to such soils. Lime, though a powerful fertilizer of other soils, is itself wholly sterile. Where, therefore, it happens to be in too great quantity, the best manure is earth, clay, or moss, especially if made into composts with dung.

Chalk is a light porous stone, very white, or of a greyish colour. It seems to have been originally formed from some mass of limestone or marble, which had been burnt into quick lime by subterraneous fires, and the calcareous particles afterwards washed to their present situation by water. Artificial chalk may be formed by collecting in a pond water which runs from a mass of quick lime, and afterwards allowing it to evaporate. The sediment left at the bottom is chalk.

This substance is generally alloyed with small particles of flint, and frequently contains large masses of that stone. Had the flint been sufficiently pulverized, and in proper proportion, in its original formation, it would have become a very hard stone. When the large masses of flint are picked from chalk, it is among the purest of the calcareous stones. A ton, for example, of chalk, contains more lime than most other stones of equal weight. It is, therefore, a very valuable manure, but unfortunately is seldom of much use where it is found, unless there be a sufficient depth of soil that is not already impregnated with it.

When chalk is found in a hard state, it is commonly burnt into lime before it is used; but frequently it is found in a soft state, at no great depth below the soil, and is then applied as marl.

4. *Marl.*

Of this there are various species, viz.

1. Stone marl.
2. Slate marl.
3. Clay marl.
4. Shell marl.

1. and 2. Stone and slate marl resemble each other in hardness. The chief difference is, that the former commonly lies in beds of greater or lesser thickness, breaks with a smooth fracture like clay, and seldom contains marks of shells. It seems to have been originally formed of clay and calcareous earth, in a state of solution; which being intimately mixed in water, had been gradually deposited where they are now found. Some species seem to have been formed from the gradual decomposition of limestone; at least some that I have seen consists of blocks of this stone, with marl interposed between the interstices, which lies in coats around the stone. This species is very rich in calcareous matter, and falls rapidly into powder by exposure to the air. It is impossible to distinguish this marl by its colour, being red, yellow, blue, black, white, &c. according to the ingredients with which it is mixed.

Slate marl is so called from its blue colour, sometimes approaching to black; and because it generally lies in beds consisting of an immense number of plies, which separate from each other like slates. It commonly contains an immense number of sea-shells, united together by means of clay schistus.

Lord Kaimes* advises to break stone marl with hammers, in order to make it dissolve. But we conceive this a very ineffectual process: it is impossible to reduce it sufficiently by hammers; and if lumps are ploughed deep, they never dissolve until they are brought up again to the air. The best way to make it dissolve is to lay it up in long ridges, and turn it frequently. The air and frost soon accomplish the object. When required for use, the large pieces can be picked out, broken, and laid in a heap by themselves; while what is ready may be spread upon the land. It ought, however, to lie at least one winter upon the furface, before it is ploughed in. If the land has been previously ploughed, harrowing may be of use to mix it with the soil.

3. Clay marl, differs in no respect from the former, except in being softer. In many parts of England the subsoil is clay marl, or it is found at no great depth. I have sometimes found this to be the case in Scotland; but it has never been subjected to a general investigation. Many banks of deep clay I have found to be marl of more or less richness. Such banks may commonly be distinguished by their propensity to push and fall by the weather; though all banks of this sort are not marl.

4. Shell marl. Under this we shall class sea-shells, or sand and sleetch mixed with shells, found on the shores of the sea. These substances have been the primary cause of all calcareous manures. Even limestone rocks are only shells which have gradually consolidated.

Shell marl is supposed to have arisen from an assemblage of fresh water shell-fishes, which have not been buried at a sufficient depth, or had sufficient time to consolidate. The Rev. Mr. Ure, in his Report of Roxburgh, informs us, "that the shell marl of that county consists mostly of a mass of fresh water shells, chiefly the *Mytilus exiguus* (of Lister) *Helix nana, H. putris*: this last is by far the most numerous. Mud and decayed vegetables are, in different proportions, mixed with the shells, many of which are entire. All the varieties are natives of Scotland, and are found living in stagnate water, in mosses where marl has been discovered. They are extremely prolific, a circumstance which accounts for their immense number."

Shell marl is commonly found at the bottoms of bogs and marshes, and it is an additional motive, where lime is scarce, to attempt the drainage of such places. The bottoms of the ditches should be carefully examined, and even penetrated to a considerable depth, by boring, or otherwise, in order to find if marl exists below.

* Gentleman Farmer, p. 267.

On the eastern shores of the island, great use is made of sea-shells as a manure. There is one spot in the county of Caithness, near Sandside, on the sea coast, which, Dr. Anderson informs us, enjoys a perpetual fertility; being constantly sown with barley for three years, with only one ploughing, and allowed to remain in natural pasture other three years. The grass grows very close and rich, and might be cut. This spot consists of shells and sand in proper proportions.

Although such beds of shells are frequent on the western coasts of Scotland, yet the farmers are seldom acquainted with their value. I shall only specify one immense bed of shelly sand, at Fairley Bay, Ayreshire, which have been burnt with brushwood, and found to yield excellent lime, yet the farmers will not be persuaded to try them upon land. Similar beds, even richer in shells, are said to abound in the neighbouring islands. In Arran, there are great quantities of the purest shell marl, contiguous to the sea beach.

The best mode of applying such shells is, either to harrow them in with a grass crop, or lay them on the surface of pasture land, to moulder by the air, and to be trodden into the soil by the feet of cattle.

But a most abundant source of manure, in my opinion, is beds of living shell-fishes, to be found every where, either on the shores of the sea, or on sand banks, accessible at low water. Many of these beds which I have examined, consist of an immense assemblage of living shells, of various kinds; but chiefly muscles at the surface. On digging farther down, I found shell-fishes in a putrid state; still deeper, the shells were broken into small pieces, and mixed with the black colour and other putrid particles, from the muscles.

I have advised some friends contiguous to such banks, to mix up the living shells in composts, with earth or moss, with a view to putrefy them. They will thus get both animal and calcareous manure in the same shell. The broken and putrid shells, I have advised to apply immediately as a manure. The result shall be communicated to the Board.

Besides the living shell-fishes which the sea contains in immense abundance, many rivers abound in what are called horse, or pearl muscles, and other shell-fishes. The author has had frequent occasion to examine the Forth and Teath above Stirling bridge, and knows that the bottom is, in most places, full of these muscles, sticking in mud. The shells are generally of great size; the animal they contain is never eaten by man; and they never have been applied to any use, except to be occasionally opened in quest of pearls.

I have frequently met with these shells in such rivers as run with a slow current, and have a muddy bottom. Would it not, therefore, be proper to apply such fishes, with their shells, to fertilize the earth? They would be too strong by themselves, but ought to be distended by a sufficient quantity of earth, or moss, and allowed to rot before they are laid on the soil.

Suppose a ton of dung costs two shillings and sixpence, or three shillings, and that a man can pick up from the bottom of a river that quantity of these shells in a day, he must be allowed to have laid out his labour to good purpose. But it should be considered, that a ton of these shells is much more valuable than a ton of dung, as they consist wholly of animal and calcareous matter, and, by proper mixture, may produce several tons of manure. I am confident, that a man, during a summer day, may throw several tons of these shells from the bottom of a river, at shallows, into a coble boat, with no other instrument than his hands. But a drag, or other mechanical instrument, may easily be constructed, to forward the process, and raise

them from deep pools. A farther inducement should be attended to; which is, the chance of finding pearls, after the shells are opened by putrefaction.

Besides these, all the refuse of fish should be carefully collected and mixed with earth. There are several species of fish frequently thrown away by the fishermen, or suffered to rot upon the beach, which might be profitably applied as manure.

We return from this digression, to offer a few general remarks on marl. Lord Kaimes thinks good marl the most valuable of all manures; because it improves the weakest ground to equal the best borough acres. He gives an example, where its superior effects were discernible at the distance of 120 years. He thinks it, however, too expensive a manure, if the quantity of calcareous earth be less than a third or fourth part.* This point we have already shewn the method of ascertaining.

The chief expence of marl arises from its carriage. If it be far from a field, lime is doubtless more profitable, though it should be more distant. It requires a much greater quantity of marl than of good lime, to manure a field; because the marl commonly contains a smaller proportion of calcareous matter, and that too in its crude state, which increases its weight. From this it follows, that, like lime, the richer the marl the less of it will suffice. Rich marl, though it cost dearer, is cheapest in the end; because it contains a greater proportion of lime, and the expence of cartage bears a less proportion to its value. But even poor marl may be laid with advantage upon contiguous land; because this substance conveys an addition of good soil, as well as of calcareous manure. All marl should be exposed to dry before it is carted, with a view to diminish its weight.

The most convenient way of using marl, is to lay it on the surface of land while in pasture. This is attended with a twofold advantage: that it can be laid on occasionally, without injuring a crop; and, by exposure to the air, its parts are more attenuated and prepared to mix with the soil; or if already brought to the field, it may be laid upon the surface of fallow, and either slightly gathered, or harrowed in, with wheat. In all cases, it is of importance to keep it near the surface at first, that it may be attenuated by the winter frost. When it is kept above, it gradually subsides, and mixes with the soil in its descent, so that both become one inseparable mass.—When buried down, at first, it is not so easily got up again.

I have found many beds of stone, and slate marl, upon beds of limestone that are wrought. These I have pointed out to their proprietors, and several of them have applied the marl, with great success; so that what was formerly buried under the rubbish, is now found to equal, and, for contiguous lands, even to exceed the limestone in value. Even where such marl contains too small a proportion of lime to be worthy of notice, it would be worth the expence of mixing with it an additional proportion of waste lime, from the kilns. For it is not to the lime alone that marl owes its superior efficacy; and by this plan marl deficient in lime may be corrected. There is, however, one caution to be attended to, respecting some of the marly strata, that they contain martial pyrites, or sulphur of iron. This stone is very heavy, resembles gold in its fracture, and is composed of sulphur and iron. By exposure to the air, the sulphur becomes acid, and acts as a most deadly poison to vegetation. There is no danger from this stone, if the quantity be small; as the calcareous matter neutralizes the acid, and counteracts its effects. If such be the case, most of them may be picked out in turning the marl; but if the quantity be great, I would advise to abstain from the use of such marl.

* Gentleman Farmer, page 266.

A prejudice generally prevails that marl is only adapted for sandy or light soils. This is altogether a mistaken notion; for it operates as a complete corrective of the peculiar defects of every soil. A light soil it condenses, renders it retentive of moisture, preserving at the same time such a degree of openness as permits the roots of plants to push through it; a strong clay soil it lays open, preserves its power of retaining water, while it destroys its tendency to become hard: in a word, it causes all soils to assimilate to itself. Although great part of the effect must be ascribed to the calcareous earth it contains, yet I am disposed to ascribe part of its effect to the remains of animal matter. A bed of shells may be considered as an incipient stratum of marl, or limestone; and part of the animal matter in the shells must continue united with these bodies. In limestone, this is dissipated by the force of heat, during the burning; but is conveyed with marl to the land.

Marl and shells are almost the only calcareous substances we can venture to lay upon land, in very great quantity, as they do not come immediately into action. But if very rich in lime, there are bounds which cannot be safely exceeded, and which depend upon the quality of the soil. But in all cases, the quantity necessary for a given extent of land, must depend upon the quality of the marl.

Petrifactions.

We have already observed, that a certain proportion of carbonic acid renders lime insoluble in water, but that an addition of the same acid renders the lime again soluble. Now many springs, which issue from deep chasms in the earth, are impregnated with lime kept in solution by means of an excess of carbonic acid. By exposure to the air, the acid gradually evaporates, and deposites the lime which it kept in solution. This takes place the more readily if it comes in contact with vegetables, into whose pores it may insinuate, and thus expand to the action of the air. The superabundant acid, in this case, flies off, while the lime rots and corrodes the vegetable into which it is carried by the water, and occupies its place. Thus it comes that large trees are either wholly or partially converted into lime of the purest quality.

These springs are very frequent in all parts of our island, and I esteem them valuable for the purposes of agriculture. The water should be collected into a bason, and abundance of moss or wood thrown in, which in time will be converted into the best limestone.

Where such springs happen to meet with moss or vegetables in their passage, they soon convert them into stone, and the figure and fibres of the plants are found in perfect preservation. There are two springs of that nature, on the farm of Canny Mill, parish of Carluke, Lanerkshire, which rise on the opposite extremities of a peat-bog. By the gradual accumulation of petrifactions, they are surrounded with conical eminences of considerable height, from the tops of which the springs flow, and trickle down the sides. Grass, fog, and stunted vegetables, grow on the eminences, which are living above and petrifying below. The interior parts are composed of vegetables in a petrified state: the moss around, and in the tract of the spring, is also petrified. These petrifactions are easily bruised, when just taken out; but after exposure to the air, they become hard as bone. Mr. Purdie, the tenant, had tried them upon land; but they hardened, never mixed with the soil, and produced no effect.

I tried a small experiment, by burning a few carts of them, and found they yielded very pure lime. An eminent farmer and mineralogist, to whom I showed them burnt, pronounced them the purest lime he had ever seen.

In these places, the quantity of petrifactions already formed is immense, and may be accumulated to any extent, by directing the springs over the neighbouring moss. I conceive, therefore, that such petrifactions may be converted into a profitable source of manure; and the more so, that it did not appear to me they required much fire in burning.—All that seemed requisite, was merely to destroy the remains of vegetable fibre by which the particles of lime are made to adhere.

These hints are thrown out to farmers who may have such springs in their neighbourhood, that they may avail themselves of the opportunity of procuring from them a very valuable supply of lime, and at small expence.

6. *Crystals, or Spar of Lime.*

These, like petrifactions, have never yet been applied as manure,* though they are the purest form in which lime is presented by nature. We have already observed, that crystals of lime are formed by the very slow evaporation of water in which lime had been dissolved by means of an excess of carbonic acid. These crystals, both externally and internally, affect a regular form. They break with a smooth shining surface; and the most perfect of them are of a beautiful rhomboidal figure, and transparent. When the rhomboidal figure is less perfect, they are generally possessed of a white opacity; which shows, that a portion of other earths, besides lime, has entered into their composition. They are also frequently tinged with red, or green, from iron or copper.

Such crystals are found in the cracks and crevices of lime rocks, and are burnt along with the limestone. In such situations, they cannot be considered as an object separate from the limestone, with which they are connected. But what I would chiefly direct the attention of the reader to, is, that such crystals are also found connected with metallic veins; and in rocky districts many veins are filled with them which contain no metal. These veins often run through a great extent of country, being very thin in some places; and they often swell suddenly into a great thickness. Such crystals are also sometimes found in vast masses, appended to rocks, in places very remote from any regular beds of limestone. In such situations, they might afford a substitute much more valuable than limestone; and from their extreme whiteness, might yield a most beautiful species of plaster and white-washing for buildings.

We have already stated the proportion of extraneous ingredients contained in this stone, and assumed the purest species of it, as the standard by which to compare the purity of all other lime.

Lime, united with other Acids.

1. *Gypsum, or Plasterstone.*

The combination of lime with sulphuric acid forms gypsum, or plasterstone.—This substance was lately much extolled as a manure, in consequence of some reports of experiments that had been tried in America. It was said, that being sown at the

* I am informed, there is a vein of this spar, several yards in thickness, actually working, at Ochil-hills, north from Stirling.

rate of a few bushels per acre, it produced as great an effect as a complete dose of lime. Several persons in this country were induced to try the experiment; but all that I know of soon abandoned it as useless.

Indeed it is difficult to see how this substance can produce any greater effect than so much lime. Perhaps one great effect of lime is to absorb acids which exist in the soil, and by neutralizing, render them harmless to vegetation. If lime, therefore, be already saturated with sulphuric acid, for which it has a stronger attraction than for most others, we cannot see how it should produce even so powerful an effect as when saturated with carbonic acid, or some other for which it has a weaker attraction.

2. *Phosphoric Lime, or Earth of Bones.*

We have already advised, that all bones should be laid up in heaps, among earth, in order that by putrefaction they may yield the oils and mucilages they contain.—But if the bones are afterwards picked out, and reduced to powder, they yield earth of bones; which is lime united to the phosphoric acid. Burning the bones facilitates their reduction into powder, but renders them less valuable, as it expels the remains of oil and mucilage which may still adhere to them.

All calcareous matter has been originally derived from the bones of animals. The shells of fishes we may regard as their bones, with this difference, that in place of wearing them in the inside of their bodies, like land animals, they carry them on their backs. The carbonic acid, by which the lime is made to adhere in their shells, is well adapted for their situation, but could not form a sufficiently firm compound to endure the force of muscular action in the bones of land animals. Such a compound would also be liable to dissolution, and the bones rendered liquid, even by the weakest vegetable acid that entered into the animal system. Land animals, like fishes, not only possess a power of elaborating calcareous matter in their bones, but they are also endowed with a power of elaborating phosphoric acid; which produces an insoluble compound with lime; and this compound is not very liable to be destroyed.

Bone ashes are equally powerful, as a manure, with the purest lime; for they contain no alloy of other earths, which often contaminate limestone. They answer very well as a manure, after they have served their purpose in those metallic manufactures which employ them. Hence the refuse of such manufactures should be carefully collected, and applied as manure. But the raspings of unburnt bones, for the reasons already assigned, appear much more powerful. They bear the same relation to the bone ashes which living shell-fishes bear to burnt lime. All the refuse of such manufactures as employ bones ought therefore to be carefully applied as manure.

3. *Fluate of Lime, or Derbyshire Spar.*

This substance consists of lime united to the fluoric acid, which possesses the remarkable property of corroding glass and flint. It has never been tried as a manure, as it seems to be limited in quantity, and found only in a few places. To those who reside near the places where it is found, we would suggest the propriety of trying the experiment; as we think it important that the effects of lime, in all its combinations, should be clearly ascertained.

Soapers' Waste.

This is a very powerful manure. It consists of the lime used by soap-makers in the formation of their lees, together with the refuse of kelp, or mineral fixed alkali.—From the great demand for soapers' waste, in glass-making and other manufactures,

the price is now so much raised, that it is seldom used as a manure; but though dearer than most other states of lime, yet, from the alkaline and vegetable substances united with it, a small quantity produces a great effect. The waste lees of soap have never been tried as manure. They consist of oil and animal mucilage, imperfectly combined with caustic alkali. I have set on foot experiments, with a view to try their effect as manures; which shall be communicated.

Manures produced by Fire.

1. *Soot.*

This operates as a powerful top-dressing. It is commonly sown by the hand upon grass, or upon wheat, in spring, that had suffered during winter. It may also be used for any other crop that seems to languish. From thirty to forty bushels are sufficient for an acre. When used in this way, its effect only lasts for one season. But we conceive the best way to render its effect permanent, is to lay it on the surface of land that is thrown into pasture. When pasture-land is once made to throw up rich grass, it retains, or rather increases in fertility, until the next break.

Soot is a compound of charcoal, oil, and resinous matter, which had escaped inflammation. It therefore admits of being burnt over again. It also contains volatile alkali, and other salts that are capable of being raised in vapour by heat.

2. *Ashes*

Are found to produce a very lively vegetation, though not very lasting, if the land be in crop. They answer best as a top-dressing for grass. They contain a portion of fixed alkali, and of light friable earth, well adapted for allowing the roots of plants to push through it. I have also found, in some species of coal-ashes, a portion of Epsom salt, or sulphuric magnesia; a salt highly favourable to vegetation.

In places where mosses abound, they frequently construct pot-kilns for burning the moss into ashes. These kilns are lined with stone, or wrought clay. They are first filled with dry peat; on the top of which is laid a large mass of wet peat from the moss. The inflammation of the dry peat communicates the flame to the wet mass, and by constantly filling at top, the peat continues to burn ever after, without any new supply of dry matter. The ashes are drawn out at the air-hole below, and should be put under a shade, or covered with sod, to prevent them from being drenched with rain. The burning should be slowly conducted, by keeping the kiln well covered at top, otherwise the excessive draught will dissipate most of the ashes in the air. We may also remark, that the more solid and compact the peat, the more ashes it will yield. Hence moor, or black peat, is better for this purpose than the soft, spongy, yellow moss.

Whether paring and burning land be a profitable system, has been a subject of much dispute. I conceive the opposers of this practice are right, in so far as the object in view is a system of crops. Wherever cropping is intended, paring and burning ought to be wholly exploded. But in high and elevated situations, and in those which are remote from markets, the great object of the cultivator ought to be to get the land as quickly as possible into rich pasture. If the surface be covered with a coarse herbage, and especially if the soil consist of moss to a considerable depth, burning may be very properly employed to destroy the herbage, and render the land workable. It should then be reduced, as speedily as possible, by fallow, and sown with grass and white clover seeds, either with or without a crop. Lime harrowed in

with the grass-seed, will increase the richness, and prolong the sweetness of the pasture.

This process I can recommend for land that is first torn up from moor. In such situations it is of no importance to wait for a crop: what is ready in spring may be laid down with a crop; but grass can be sown by itself during the whole of summer and autumn, and makes up, by its superior richness and duration, for the want of a crop. At all future breakings of such land, I would advise to abstain from burning: this wastes the vegetable matter in such soils, and which, on being fermented with proper manures, becomes itself a manure *.

Burnt clay, or till, produces very good effects when applied as a top-dressing to pasture land. A gentleman of my acquaintance set on fire a large heap of clay schistus, called by miners dauk, taken from a coal-pit, of which it formed the coal-roof; on examining the stratum, I found part of it contained magnesian schistus, and this part yielded by far the best ashes. It was placed upon brushwood, and when once fairly kindled, continued to burn of itself. The ashes being spread upon a pasture field last autumn, caused it to throw up a more early and a more vivid verdure this spring, than any field around: the grass is now extremely luxuriant, and close in the pile. Some were ploughed in with a crop last season; but did not produce any sensible effect. From hence I infer, that burnt clay answers best as a top-dressing.

The same may be affirmed of coal-ashes, unless they be properly mixed with the dunghill, and saturated with animal or vegetable juices.

At glass-houses, forges, and a variety of manufactures where much fuel is consumed, vast quantities of coal-ashes are wasted, which might be converted into valuable manure; particularly for clay land. Such ashes should be passed through a search, similar to that used in gravel-pits, to separate the fine particles from those that are large, or vitrified. The fine particles may be either used immediately, as a top-dressing for grass grounds, or, if mixed with the urine and filth accumulated at these works, they would become excellent manure for any land. By thus accumulating all the urine and filth of such works into one mass with the ashes, the health of the workmen would be much promoted. We would earnestly recommend this practice at cotton-mills, and other works, where great numbers are crowded into one building: The ordure and filth that is accumulated at these works infect the air with noisome exhalations; whereas were they properly saturated with ashes or earth, the exhalations would be prevented, and a considerable value of manure procured.—At some works, and even at many farms which I have seen, the filth is washed away by water; which ought not to be permitted, as it contaminates the rivers, and deprives the country of valuable manures.

The same observations are applicable to the soapy suds, and lees accumulated at bleach-fields and fulling-mills. These should either be saturated with ashes and earth, or collected into reservoirs, from whence they can be occasionally carried in a liquid state, and poured upon the surface of land; they will soon amply repay the trouble that is bestowed upon them. Those lees, however, that are composed of acids should be avoided; though I am not certain but the application of acids to land

* For moors that admit of being cut with the plough, I have already pointed out a far preferable method of converting them into sweet pasture. And for bogs that will not support the tread of cattle, I have described the method most successfully practised by John Smith, Esq. of Swinridge Muir.

would, in particular circumstances, be a great improvement. This is a problem which experiment alone can solve. The lees that are voided from such works occasion the destruction of fish in those rivers into which they flow. By applying them to land, instead of a nuisance, they are converted into a public benefit.

Sea-Salt.

It has been a subject of dispute whether this substance, or any other salt, that ranks among the perfect neutrals, be of any use as a manure.—On the one hand, Dr. Anderson, in his Essays already quoted, relates an experiment which seems decisive against the utility of common salt as a manure. Having fixed a stake in a field of grass, he sprinkled a circle round it of six feet diameter, with common salt; being thinner towards the circumference, and towards the centre near an inch thick. The grass made no better appearance than that which grew upon the rest of the field, and the spot, for some years, could only be distinguished by the stake, which was left there on purpose.

Dr. Home, in his Essays on the Principles of Agriculture and Vegetation, p. 90, found that sea-salt, in the proportion of 1 oz. to 6 lb. of earth, acted as an enemy to vegetation. By a future experiment, p. 96, he found that sea-salt, dissolved in water, and added in small quantities to a poor soil, proved rather hurtful than beneficial to vegetation.—The salt he used was very pure.

On the other hand, Mr. Wedge, in his Report of the County of Chester, p. 68, relates experiments which seem equally decisive in favour of the power of salt as a manure.—A gentleman having drained a piece of sour rushy ground, laid on one part of it, in the month of October, refuse salt, after the rate of eight bushels to the acre; and on another part sixteen bushels. All vegetation was soon extinguished by it, and continued so until the end of May following; when the part which had got least salt began to throw up very rich grass. In the month of July, the other part produced still a stronger crop. The cattle were remarkably fond of it, and during ten or twelve years, the land has continued to exhibit a verdure superior to the neighbouring closes.—The author continues to adduce other experiments, which lead to the same conclusion.

Mr. Pomeroy, too, in his Report of Worcester, p. 34, informs us, there are persons in that neighbourhood who prefer foul salt to all other manures, and even apply it under the disadvantage of a heavy duty, payable on the spot.

We might proceed to adduce examples innumerable on the opposite sides of this question: the facts on both sides seem well authenticated; but they leave us wholly at a loss on which side to determine. There may perhaps have been circumstances not attended to by those who have drawn conclusions unfavourable to the power of salt as a manure; this power may possibly not reside, at least in an eminent degree, in the sea-salt itself; but in the bittern, or some other earthy salt with which it is naturally contaminated. In the examples that are favourable, it was the refuse, that is, the part most loaded with bittern, that was used.

From the experiments of the late Sir John Pringle, it appears that sea-salt, if below, or exceeding a certain proportion, is a powerful septic; that is, promotes putrefaction in those bodies with which it comes in contact. Now whatever promotes putrefaction must be a manure.—But the septic quality of sea-salt is far inferior to that which the bittern, or muriate of magnesia, and the muriate of lime, salts which abound in the refuse of sea-salt, possess. These latter salts are perhaps the most septic of any bodies with which we are acquainted; and from their extreme attrac-

tion for water, have a tendency to keep the land perpetually moist. If then reasoning from the qualities of the bodies in question, can be of any avail, we would be disposed to side with those who esteem the *refuse* of salt, at least, a powerful manure. But if applied in such quantity as completely to saturate the soil, it would certainly kill every plant, and continue to prevent vegetation, until its excess were washed away.

However this question may be decided, it would certainly be a desirable object, both to agriculture and manufactures, to obtain a repeal of the duties on salt. This substance, sown upon pastures, if it did not increase the quantity, would at least render the grass highly palatable. Cut grass, and every species of food given to cattle, might receive a small proportion of it. Cattle are so fond of this salt, that they lick up even the earth that is mixed with it. This is well known to the Americans, who make artificial licks in the track of cattle through the woods, round which they lie in ambush to shoot them. I have known cattle prefer coarse stunted grass that was occasionally covered by the sea to the richest pastures.

Nitre.

Many authors make this salt the *pabulum vitæ* of vegetables. But it appears from Dr. Home's experiments, already quoted, p. 89, that saltpetre, mixed in the proportion of 1 oz. to 6 lb. of earth, rather retarded than promoted vegetation; yet when added in small quantities dissolved in water, it promoted vegetation considerably, p. 96.

It would appear from many experiments, that when a plant is so situated, that it is compelled to draw up any salt whatever into its substance, or when the roots cannot extend themselves without coming in contact with saline particles, it soon languishes and dies: yet every process by which the saline ingredients in a soil are made to decompose, and assume new arrangements, contributes highly to its fertility. Of these no process is more beneficial than that by which nitre is formed. Although, therefore, this salt should not of itself greatly promote vegetation, yet the putrefactive process excited in the soil, and which generates nitre, is the real cause of its fertility.

We beg leave to add one remark more before we quit the subject of salts. We conceive that any salt whatever that is capable of exciting putrefaction, and that powerfully attracts and retains moisture, may be usefully applied as manure. No salt promotes vegetation by entering into the substance of plants, but acts upon the soil itself. Many other salts possess the properties we have described in a much more eminent degree than nitre, and the most beneficial of them may be procured at small expence.—We except all salts with metallic bases, and all which are of a caustic nature.

Vegetable Manures.

Upon these it will be unnecessary to be very prolix, as they are only to be procured in certain situations, and most of the vegetable manures are improved by being mixed with animal matters in the composition of dunghills.

1. *Oil Cake.*

This is the refuse of lint-seed, rape-seed, &c. after the oil is squeezed out, in the manufacture of these oils: these cakes still retain a portion of oil, and highly concentrated mucilage, and are therefore usefully applied to the feeding of cattle. They are also frequently as manure. Ten hundred weight is esteemed sufficient for an

English acre, and the cake costs four pounds a ton. [Mr. Lowe's Report of the County of Nottingham, p. 17.]

2. *Refuse of Malt.*

The vegetating germ that is detached from malt in the act of its formation, and the grains of malt after the wort is extracted, when allowed to rot, are an excellent manure. Six quarters may serve an English acre, and cost about five shillings per quarter.

I am inclined to think that the water which has been employed in steeping barley with a view to its malting, might be successfully applied as manure. It must contain a considerable portion of the mucilaginous extract of the barley. An eminent distiller assured me he had been able to ferment it into spirit; though like all spirit from raw grain, it was of a very nauseous quality. If capable of the vinous fermentation, it must be much more so of the putrefactive. It would be desirable that malting houses and distilleries were situated in the country, where such water might be directed over the surface of land; and all the filth accumulated at such works, applied as manure. But as the matter stands, all the foul water accumulated at such works, and in towns, should be directed into reservoirs, where it may be absorbed by ashes, or straw of dunghills. I am confident it would be the interest of farmers to convey such water to their land even in hogsheads, and scatter it upon their new sown crops, or upon their pastures.

3. *Sea-Weed*

Is much used as manure along the coasts. What is blown ashore by the winds is commonly laid up in heaps, and allowed to rot. On rocky coasts where this weed abounds much, it is cut with sickles, at low water, and burnt into kelp. In other places where the quantity is not sufficient for this purpose, it is cut for manure. The plants which grow within reach of the coast require stones, or rocks, to attach themselves to; and on sandy beaches it would be an object for the farmer to lay large stones within sea-mark, for the weeds to fasten their roots upon. This can commonly be done from the cleanings of contiguous fields. A few acres scattered with such stones, yield a very valuable supply of manure. There is a large broad-leafed plant in the sea (*Fucus saccharinus, sweet fucus, or sea-belt*) of a brownish yellow colour, grows from one stem, and chiefly in pools which are sheltered from rolling waves. It seems to resemble an animalized substance. What is blown on shore, is commonly collected with other weeds. But on looking down from a small boat, in a calm, I have seen immense beds of it growing in the bottom of the sea, and reaching the surface at low water. I conceive it might be cut by hooks fastened to the ends of poles, and rotted for manure. I cannot affirm whether cattle would eat this plant; but the leaves, when fresh, are not unpleasant to the taste.

Sea-weed is either spread fresh upon the surface of pasture lands, or is ploughed in for barley, or is applied for the production of potatoes. For the latter crop, it is found to be an excellent manure. When this substance is laid up in heaps to rot, it should always be mixed with a portion of the best earth, or moss, that can be procured; for experienced farmers have assured me that it is thus made to go much farther, and its effects continue much longer than when rotted by itself.

These plants contain a large portion of matter resembling animal mucilage, and common salt. A person acquainted with chemistry informed me, but I cannot vouch the fact upon my own experience, that sea-plants, when bruised and macerated

with water, in their fresh state, yield no saline ingredient except sea-salt. That when burnt, they yield mineral fixed alkali, or soda, with a portion of sea-salt: and when rotted, they yield vegetable alkali or pot-ash, but no soda.—These circumstances, if authentic, seem to prove that the alkalies are the effects of putrefaction, or of inflammation, and may be varied according as one or other is applied.

4. *Green Manures.*

It is common, in many places, to sow certain plants, and after they have grown some time, plough them down as manure for a crop of wheat. Peas, vetches, and the second crop of red clover, are often treated in this manner. Buck wheat is also frequently sown in order to be ploughed down for wheat; but is not so generally esteemed as some others.—I am disposed to agree with Lord Kaimes * that it is unprofitable to plough down a crop with a view to manure a field. It is certainly better to cut such a crop green, and feed cattle with it, as it will thus yield a profit on feeding, as well as dung.

Of Composts.

When dung and lime are not wanted for immediate use, great advantage is gained by making them into composts. If dung be allowed to rot too long, it moulders into earth, and becomes effete. But by mixing it with earth, it communicates its fetid effluvia, and the whole strength of it is thus preserved. The putrid fermentation cannot be conducted so slowly, and so perfectly, but a part of the useful matter may be lost. By mixing therefore fresh dung with earth, a great saving is obtained. Dung is more apt to lose by exhalation in summer than in winter. It would therefore be an object to lay up in composts the dung that is accumulated in summer. This can easily be done, occasionally, as a few cart loads of it are ready.

Composts are formed in various ways. In some places where there is a head, or foot ridge, too high to admit the water to be rapidly discharged from the field, they plough it, then dash it full of lime or dung; and after frequent ploughings, spread it upon the field. After the lime is sufficiently mixed, they sometimes gather the earth into a heap with the spade, and mix it with dung. Sometimes the whole operation is performed by the spade, which is certainly the best method.

The earth that is gathered from the bottoms of ditches, is the best that can be used for making composts. It is the lightest part of the soil, as it has been carried thither by water. It contains also a portion of vegetable matter. To this we may add the cleanings of roads, especially if they be laid with limestone, as is done in many parts of the country. These consist mostly of earth that has been worn from stone, and is not therefore apt to bind. It is also mixed with a portion of animal dung. But the earth that answers best for most composts is peat. This fills up the pores of a sandy or gravelly soil, without diminishing its friability. Even when applied by itself to such soil, it increases its fertility. But upon a hard clay soil, it is necessary to have it fermented with lime, or dung, or a portion of both, before it is applied; and completely reduced by frequent turning, to make it mix properly. If this precaution be neglected, it dries, hardens, and cannot be properly mixed afterwards.

* Gentleman Farmer, p. 258.

The only species of soil on which moss should not be applied, is peat, or moor soil; such soils have already too large a proportion of this substance, and are hence apt to swell and blister. An addition of this matter increases the evil. In all soils therefore disposed to heave or blister, moss should be avoided.

It is common, in many places, to pare the moorish and uncultivated parts of the farm, and make the turf into composts. This is certainly a pernicious practice, as it robs those parts of soil where it is scanty, to accumulate it in others; where perhaps this species abounds too much. Some again apply the light spongy surface of moss to this purpose; but the species we would recommend, is the densest that can be found, which is generally at the bottom. It should be mixed up before it dries and consolidates; if this cannot be found, a bank of deep rich earth, is preferable to paring the surface.—Moss, when intimately mixed with a clay soil, keeps it open, and prevents caking. I have known several hard clays, that could not be made to yield crops, by any other means than by composts of moss.

In ordinary situations, it is of importance to cross soils by composts: if two contiguous fields be one clay, the other sand or gravel; the compost formed in the clay field should be laid upon the other. But I would not make a compost with sand, it cannot retain, or ferment with the juices of the dung: with lime it would consolidate into a hard stone. The sand itself, if in sufficient quantity, would answer the purpose much better; I am aware that a certain proportion of sand, renders clay more tenacious: if this proportion be exceeded, the clay becomes perfectly friable. Now, even in the hardest clays, there is but a small proportion of real clay, or alumine; an addition of a proper proportion of sand, would therefore turn the balance in favour of its friability. Perhaps, next to marl, the best alterative for stiff clay, would be a dressing of hewn-stone chips, or sandy gravel. That clay, on the other hand, renders a sandy, or gravelly soil, much more fertile, I have seen proved by the most successful experiments.

In making composts if only one species of manure be used, it is only necessary to lay the manure and earth in alternate layers, in a long ridge; and top it so that rain may not wash through it. For hard clay, or moss, I would apply lime as hot as possible; perhaps even in shells, that it may exert upon them the full force of its corrosive power.

When both lime and dung are used, there should be first a stratum of earth, then one of dung; then earth, lime, earth, dung, &c. always interposing a stratum of earth between every two beds of lime and dung: the reason of this is, that lime, if mixed with dung in the first stage of its putrefaction, corrodes and dissipates its effluvia: as the lime here is intended to absorb the putrid exhalations of the dung, it should not be so caustic as in the former case. After the first fermentation of the dung is completed, the whole should be turned to mix the ingredients; and this operation should be repeated, until the mass be sufficiently pulverized: this is done by cutting the compost, with a spade, in perpendicular slices.

It would be absolutely unpardonable to neglect to mix in a compost, all the weeds that have not run to seed, which can be collected from the neighbouring fields; the weeds also which grow upon a compost, should be buried down, before they run to seed.

Composts are a species of artificial marl, and if the parts are sufficiently pulverized, may be used for any crop. If this should not be the case, they are best applied as top-dressing for pasture lands; the parts are thus gradually crumbled down, and beaten into the soil by the feet of cattle, or washed in by rains.

I 2

Remarks on the Application of Manures.

It is almost unnecessary to observe that manures produce no good effect, unless the soil be laid dry, and cleaned of weeds; for manures may as well be buried in water, as laid upon a soil that is full of springs, or on whose surface water is allowed to lie stagnant. Manures also pay no respect to the quality of plants; and if the soil be over run with weeds, cause them to grow with such luxuriance, as to choak the crop.

The quantity of manure necessary to produce a given effect, must depend upon its quality, and the nature of the soil to which it is applied; upon this no general rules can be given, and every man's prudence is his best directory.

A soil that has been frequently dressed with one species of manure, begins to be less and less affected with it: hence frequent change from dung to lime is attended with advantage; but if both can be applied at once, they produce the most powerful effects.

Manures are generally applied after fallow, with wheat, with barley, with potatoes, and drilled crops; or as top-dressing to lands in pasture.

After fallow, manures are very properly applied, as they can be well incorporated with the soil, and by the fermentation which they excite, prevent its future binding. Dung and animal manures are best adapted for the production of corn crops. Severe cropping after lime empoverishes the soil; but this manure displays its most powerful effect in raising sweet and palatable grass; with lime therefore land should be soon thrown into pasture, where it will recruit its strength for future cropping.—Hence a general rule,—dung and crop, but lime and rest.

It is an important question, hitherto not much attended to—whether manures should be buried deep in the soil, or kept near the surface? I am inclined to the latter opinion, (except in cases which shall be afterwards specified) both from theory and experience; manures, when buried deep, are excluded from the action of the air, on which their fermentation depends: they are sunk also beneath the roots of the plants; whose side roots seem to be the chief instruments by which they draw up moisture. It would appear that the action of air, and the sun's light upon the surface soil impregnated with manure, contribute to concoct the juices which enter into the roots of plants; a circumstance which cannot have place, when the manure is buried deep; besides it is more natural to expect that manure, placed near the surface, may sink down to its proper level, than that what is buried too deep can exert its influence upon the plant that grows above it.

I have observed dung that had been ploughed deep into a clay soil, turned up again next season, without any apparent change; while what was laid upon or near the surface, was wholly rotted into vegetable mould.—Mr. M'Kenzie of Glasgow, as stated in the Appendix to Sir John Sinclair's Report, always spread the dung upon the surface of the land, with a powdering of lime above it, to absorb its exhalation, and afterwards pressed it down with a roller; by applying lime and dung in this manner, a rapid putrefaction was produced, and high fertility was the consequence. I found this practice answered best in wet seasons, when the dung was kept moist by frequent showers. When the dung was covered in with a slight furrow, and the lime afterwards harrowed in with the seed, I could not perceive any sensible difference. Were the dung short enough to admit of it, I would harrow it in as well as lime with the seed: by this practice the manure is thoroughly incorporated with the

surface soil, and is in no danger of being buried out of the reach of sun and air. The fermentation excited at the surface, prevents the future hardening of the soil.

It is commonly supposed that lime is an improper manure for potatoes; and indeed if applied hot, and in contact with the sets, it causes them to scab—but the same effect would arise from an over-dose of very strong dung; and may be imputed to the lime acting as a corrosive, or simple salt; but if the lime be spread upon the surface of the land after the potatoes are planted, or laid upon the tops of the drills, its corrosive power is destroyed by reabsorbing carbonic acid from the atmosphere, before it comes into action, and it proves an excellent manure for potatoes.

The hardest clay soils yield excellent potatoes with lime. The best method is to lime heartily before winter, and lay the land in drills: in spring lay dung in the hollows with the sets, and cover them with the double mould-board plough. The earth that is most pulverized by the frost, is thus put next the sets; and it should not be laid deep at first. If dung cannot be got, after liming before, or during winter; in spring cross-plough, and brake the land; lay the sets on the surface in rows, and cover them with the plough. If the lime be in sufficient quantity, it causes clay land to produce excellent potatoes without dung.—Wheat answers well after potatoes; but they should be set early, that the land may be ready in time.

It is hoped we may be indulged in a remark or two respecting potatoes, as from any thing that has been collected, neither the general practice, nor opinion, are adequately enlightened respecting this most useful plant; I conceive it well calculated wholly to supersede the use of fallows, except what may be necessary to reduce the land into a proper form for cultivation, and to clear it of stones. I have observed wheat, for which fallow is commonly adopted, to grow as well on that part of a field which had been in potatoes, as in that which had been fallowed; the manures applied to both being the same. In the one case, there was only one crop obtained at great expence; in the other two, with equal expence of manure.

Even the wildest land that admits of being ploughed, may instantly be rendered productive by planting it with potatoes. Suppose such land to be over run with heath, or rushes; burn the heath, and cut down the rushes, that they may not interrupt the plough; upon the surface spread dung, and if it can be previously limed, so much the better: take a plough with a double feather, one upon the sock, and another upon the wrest, and cut a straight furrow; on the back of this lay the sets; and by the return of the plough throw another furrow over them; this throws the whole into drills, on the top of which potatoes are planted; they resemble lazy-beds formed by the plough: the drills should be aided with the spade, where the turf does not cover the sets. I have seen an acre of the poorest land produce a value equal to ten or twelve pounds in this way. If the land is not sufficiently pulverized by this first operation, the drills should be reversed, and planted with cabbages, or the same crop continued; by this process, the cultivation of waste land is made instantly to pay itself, with profit. If there be no market at hand, the produce may be given to cattle.

Lime is seldom applied with turnips, being esteemed by some of no utility with that crop. But I should think it might have some effect, at least, in killing vermin, which infest turnips. It is a very absurd practice to sow turnips, or any crop of that nature, broadcast; the best method is, after repeated ploughings, and brakeings, to clean and pulverize the land, to lay it up in drills of proper wideness; place dung in the hollows, and cover it with the double mould-board; this forms new drills above the dung, having smoothed these with a roller, sow the turnip seed upon their tops by a machine.

The head and foot ridges, which are left vacant for turning the horses, during the dressing of drill crops, should, after these operations are finished, be planted with cabbages or greens. A farmer who has got all his land inclosed, and in good order, should have no spot appropriated for pot-herbs; these thrive much better in the field, and may be planted in a corner of the land that is allotted for potatoes or turnips. Onions are perhaps the only exception to this rule; they thrive the better, the longer they are continued on the same spot.

Top-dressing land while in pasture, increases its fertility exceedingly; and is attended with this advantage, that it can be done occasionally, when convenient. Even land that has been ruined by severe cropping, after lime, or marl, will recover if thrown into pasture, and top-dressed with the same manures. Dung also produces powerful effects in this way. The best time for applying them, is towards the close of the season, and to leave a rough herbage during winter: but if both can be used, the lime in powder, being spread above the dung, their united effects are still more beneficial. Making them into compost is the most beneficial method of any.

I never could perceive any foundation for an opinion which generally prevails, that lime, or dung, laid upon land during winter, lose their efficacy. I can, at least, vouch the fallacy of this opinion respecting lime; having often spread it during hard frost, and frequently on the surface of snow a foot in depth; if any difference could be perceived, it was that lime applied at this season, produced even better effects, than what was laid upon the same field during spring: this I imputed to the openness of the soil after the frost went away, which caused it to imbibe, and more thoroughly to incorporate with the lime. It has been observed that lime which has been freezed, never takes a band in building; but this cannot happen except when the absurd practice of *souring* lime, as it is called, is adopted; a practice which ought to be wholly exploded.

It is surprising that no person has yet attempted to apply dung, by solution in water. The Japanese, if travellers may be credited, certainly far surpass all the western nations in agricultural skill; or at least in the assiduity with which they practice this art, and are said to apply all their manures in this manner; they plant all their crops in rows, keep them perfectly clean, and drop water, in which fermented dung had been soaked, along the rows after the plants have sprung; by this method they make a small quantity of dung to produce a great effect. That people are said to collect, with the utmost assiduity, every particle of filth that can be got; even putrid water is carefully sought to manure their land; and when on a journey, they pick up from the road the dust among which the urine and excrements of their cattle have dropped, and fetch them to their dunghill; by these means the salubrity of the air is preserved, and their country raised to a pitch of fertility of which we can form no idea.

I have frequently dropped soap-suds, foul kitchen water, and juice of dung, upon the roots of potatoes, after they had sprung, of cabbages, and of greens; I have also watered ground in this manner, that was intended for certain garden seeds; and always remarked that those which received this treatment, grew more luxuriantly than similar plants which had not: I took care not to touch the leaves of growing plants, with the juice, though perhaps this precaution might be unnecessary.

Any farmer might easily try this experiment upon a grass field; let him top-dress a certain extent with a known quantity of dung, and water an equal extent with the juice of a similar quantity: for this purpose it is only necessary to soak the dung in a small pond, in some corner of the field, into which he has conducted a

rill of water. A hogshead, placed upon a cart, will convey the juice to the spot; where, on pulling out a few pins from its lower end, and driving the cart slowly along, the juice will be equally distributed. If the fertility produced by the juice be greater on the same extent, or equal on a greater extent, there is an evident advantage gained. Lime can be easily applied in this manner, if it is hot from the kiln; because it is then soluble in water. Thus the juice of dung and lime may be applied alternately, and a small quantity be made to go over a great extent of surface.

SECTION II.

Effects of Manures upon the Soil.

As this subject has not been much attended to, it cannot be expected that we shall dissipate the obscurity in which it is involved. This can only be effected in consequence of an accurate analysis of the component parts of every species of soil in its original state; compared with the ingredients it contains after it is completely changed by working and manures. No individual is able fully to execute such a task; and it may be deemed by some unimportant. Art, we admit, may go a great way, but never can attain its utmost perfection without the assistance of science.

It is my intention to offer a few facts which have fallen under my own observation, aided and illustrated by facts which have occurred to others; together with such reasonings and conclusions as seem fairly deducible from the premises. If they excite the attention of others towards this subject, my object shall be obtained, and I shall be happy to see my mistakes corrected by a fuller investigation of facts.

I conceive that manures operate upon a soil by destroying the pernicious ingredients it may contain; which we may call *medicating* the soil.—By reducing it to a proper consistency.—By rendering it retentive of moisture.—By exciting a degree of fermentation, attended with heat.

In treating this part of our subject, we conceive the most perspicuous order we can adopt, is 1st. To enumerate the various species of soils, as they exist previous to cultivation; and point out certain pernicious ingredients which some of them contain. 2d. Endeavour to shew how working and manures render these soils more productive.

1. *Enumeration of Soils, &c.*

Soils, as they exist before cultivation, may be divided into primary and adventitious. By the first I mean those that have not changed their present position, at least from any cause which now operates in changing the earth's surface; and they may be subdivided into clay, till or schistus, moss, which is a vegetable and has grown where it is now found, rock-soil, which is composed of decayed particles of the rocks on which it rests. By the last I mean those that have been brought into their present position by the washing of water. They may be subdivided into marly soils, sand, gravel, loams of various tenacity. The latter are chiefly found in hollow situations at the bottoms of hills, or upon valleys on the banks of rivers, and consist of particles of earth that have been washed down by floods. Sand and gravel have been thrown into their present situation by rapid torrents; and loams have been gradually depo-

sited from stagnant water. Besides these earthy ingredients, all soils are covered with a stratum of vegetable mould, produced from vegetables which have grown and decayed upon their surface. Washed loams also contain a portion of this mould in their substance, which has been conveyed and deposited along with them in their original formation.

Of the primary soils, most of the strong clays and tills, in their original state, are covered with a very thin coating of vegetable mould, and the substratum is wholly unfit for the production of vegetables. Such are commonly distinguished by the appellation of *thin stapled soils*. They are also frequently called *sour* or *cold bottomed soils*.

I have discovered in such soils three ingredients, two of which at least are extremely hostile to vegetation. These are martial pyrites, aluminous schistus, and magnesian schistus.

1. *Of Martial Pyrites*.

This substance, in the new Nomenclature of Chemistry, has acquired the name of *sulphure* of iron, being a compound of iron and sulphur. We already observed that when it exists in considerable masses, it forms a hard, and very heavy stone, which breaks with a golden coloured fracture. But I have found it to exist throughout primary soils, sometimes in small masses like nuts; but more frequently in particles which cannot be distinguished by the eye. When such soils are first turned up to the air, they appear of a white, or yellow, and sometimes of a bluish colour. After long exposure the sulphur attracts oxygen, or the pure respirable part of the atmosphere, and forms with it sulphuric, or what is commonly called vitriolic acid. This acid unites with the iron with which the sulphur was formerly combined, producing a salt called *sulphate of iron*; but, in common language, improperly called *copperas*. By long exposure, and frequent turning, such soils acquire a red colour, which is owing to the rust of iron after the salt is extracted from it. After repeated working and manuring, this soil begins to assume a black colour, and approaches to the resemblance of dark loamy soil.

It can hardly be questioned that copperas, or the salt formed from martial pyrites, is destructive to vegetation. This I have had occasion to observe at copperas works; where hedges, and every plant which this salt is allowed to approach, are suddenly killed. In the original formation of this salt, the acid is superabundant; that is, exceeds the quantity which the iron can absorb. Hence, in copperas works, they employ old iron to absorb the superfluous acid. Whether the destructive effects of this salt be owing to the loose and uncombined acid, which is left at liberty to attack and corrode the fibres of plants, or the metallic salt itself possesses a styptic corrosive power, similar to other metallic salts, I shall not pretend to determine; but the fact cannot admit of doubt.

Dr. Home, p. 30 of his treatise already quoted, relates an experiment by which it appears, that a small quantity of this salt rendered a large portion of rich earth extremely unfruitful. But I conceive he has committed a mistake, when he seems to ascribe the effect to the iron. I regard the iron as perfectly harmless, nay, a very proper receptacle for the roots of plants; and impute the bad effects to the acid formed from the sulphur, with which iron, in its natural state, is universally impregnated. Modern chemists impute the formation of iron, as well as sulphur, to the decomposition of animal and vegetable substances. Being originally formed in a state of union, they continue united, until, by exposure to the air, the sulphur is aci-

dified; and the salt that is produced is either washed out of the soil, or destroyed by the action of manures.

2. Of Aluminous Schistus.

This substance occurs less frequently than the pyrites, and wherever I had occasion to remark it, there is generally a large portion of the former substance connected with it. This substance, in its original state, consists of sulphur united to clay. By exposure to the air, the sulphur becomes acid; which continuing united to the clay, forms alum, a salt with which every one is acquainted.

During this process of nature, the acid, as in the former instance, is always superabundant. But though this were not the case, alum, in its purest state, is known to act as a powerful poison to vegetation.

3. Of Magnesian Schistus.

I call by that name a combination of sulphur with magnesia, which I have found to abound in many soils. The peculiar properties of magnesian earth were first discovered, and illustrated, by the celebrated Dr. Black: but it is not perhaps known to prevail so extensively throughout nature, as it really does. As in the two former cases, the soil containing this schistus being exposed to the air, the sulphur becomes acid, and the salt which results is sulphate of magnesia, or Epsom salt. The acid is frequently superabundant; or exceeds the quantity which the magnesia can neutralize.

This salt I had long mistaken for one or other of the two former, until certain appearances induced me to collect it separately, and make some trials to ascertain its nature. My friend Mr. Cooper, surgeon in Glasgow, a gentleman of eminent professional abilities, and a skilful chemist, to whom I sent a specimen, determined it, by analysis, to be Epsom salt.

This salt, or rather the schistus from which it is formed, is perhaps more generally diffused throughout nature than any of the former. The magnesian salt, formed from it, where it is not connected with an excess of acid, instead of being hurtful, is highly propitious to vegetation. From the experiments of Dr. Home, already quoted, it appears, p. 96, that saltpetre, applied by solution in water, made the soil capable of producing a fourth more, and by corollary 3d, it appears that "Epsom salt applied the same way, is pretty nearly equal in its nutritive power to saltpetre." The Doctor's conclusion is merely the result of one experiment; but in order to ascertain the matter precisely, it would be necessary to vary the proportions of the salt, and its mode of application.

I have discovered immense beds of magnesian schistus in most parts of the country, many of which are not contaminated by a superabundance of acid. Where this substance is mouldered by the weather, and the salt in a state of formation by exposure to the air, trees, shrubs, and plants of every kind, grow upon it with the utmost luxuriance. During the driest weather, it always feels soft and moist below your feet, as if you were treading upon tallow. This I impute to the deliquescent nature of the salt, that is, its attraction for moisture.

This substance then, if laid upon the surface of land, would prove a valuable manure. It must be used as a top-dressing, that by exposure to the air, it may moulder, and form its salt. Ploughing it down would prevent this, and render it useless. But the way to bring it most rapidly into action, would be to burn it before it is applied.* This can easily be done by laying a heap of it upon brushwood, and

* Perhaps mixing it with lime fresh burnt, might answer.

when once fairly kindled, it continues to burn of itself, from the oil it contains. This oil closes its pores, and prevents the admission of air to form its salt. This source of manure appears to me inexhaustible, and its good effects are evident from the experiment already mentioned with the coal-dauk, which was conducted under my inspection. Though the substance employed in this experiment be, comparatively, poor in magnesian schistus, yet its beneficial consequences are visible.

The salts we have been describing are sometimes found mixed in the same mass. Sometimes one, and sometimes another occurs; but, in general, the aluminous salt never occurs, without a large proportion of the sulphate of iron.

I first remarked these salts, formed like hoar-frost, on the backs of fur-slices, in land that had been torn up from moor during winter. I had also frequent occasion to see them formed on land where the old high ridges were levelling down with the plough, and especially where the summit of the old ridge was penetrated to some depth. I frequently collected them from the edges of ditches, where there was a thin depth of soil, and frequently from the mound of earth that had been thrown out of the ditch. I never remarked such salts in lands that had been long and well cultivated; but in many of these, where the subsoil had been recently opened by a ditch, I have collected an efflorescence of these salts. I cannot affirm whether such substances occur in loamy, or washed soils, as I never had opportunities of examining them: and my object was rather to find out the cause of infertility in primary soils, than to investigate those that are by nature fruitful. The salts occur most frequently in land that had been exposed to frost in winter, after a tract of drought in spring. One stratum of small crystals pushes outwards after another, and by their expansion, they serve to open and pulverize the soil. They form more rapidly, not only in consequence of exposure to the air, but also to the sun's rays. Moisture is also necessary to their formation; but heavy rains wash them to the bottom of the furrows, and carry them away.

These salts I sometimes scraped from the surface of ploughed land, where they appeared, like particles of hoar-frost, mixed with the soil. Sometimes I cut out pieces of earth, at different depths; and having exposed them, during some months, to the weather, upon a hollow piece of clay, or in a flat earthen vessel, to intercept the moisture that might flow from them, they were frequently found to contain a portion of these salts. In dry weather, the moisture that had washed from the pieces during rains, was occasionally sprinkled upon them. After a sufficient exposure, the pieces were washed in boiling water, and the solution filtered through paper. This liquor I sometimes boiled down to the point of saturation, and obtained the salts in a crystallized form.

The salts may be distinguished by the taste. Copperas, or sulphate of iron, has an inky taste, alum a sharp astringent taste, and sulphate of magnesia, or Epsom salt, a gently bitter taste. This last may also be distinguished from alum by its extreme solubility in water, which rapidly dissolves its own weight of the salt, when cold; whereas fifteen parts in weight of water are necessary to dissolve one part of alum, and the solution is slow. The magnesian salt may also be distinguished from the others by the figure of its crystals, which consist of soft silky needles, resembling silver in whiteness. A small portion of copperas may be detected by its communicating a black colour to an infusion of tea, or galls.

Superabundant acid, in the liquor, may easily be detected by dipping into it a slip of paper stained with the bark of radishes. If there be uncombined acid, it will change the purple colour of the paper into a red. This might easily be applied as a

test to discover if soils of any kind contain uncombined acid. It would only be necessary to steep a small piece of such soil in boiling water, and then apply a slip of the test paper. Such an occurrence is always a most unfavourable symptom. For if copperas and alum be hurtful to vegetation, how much more must the uncombined acid itself, which is the sole cause of their hurtful tendency?

Dr. Home, p. 91, found "That flowers of brimstone, mixed with earth, promoted "vegetation at first; but in a month's time destroyed the plants like a poison." I would account for this fact by supposing, that the sulphur had, by this time, begun to acquire some degree of acidity, from exposure to the air. But I conceive the sulphur itself, divested of oxygen, to be harmless.

Whether there be any pernicious ingredients in soils, besides those I have mentioned, or whether they abound in all soils, I cannot determine. I never had opportunities of carrying forward my inquiries on this subject to a general conclusion; and what is here stated is rather with a view to show that something *may* be done, than that any thing decisive *has* been done. Perhaps such ingredients prevail in most soils sufficiently to obstruct vegetation, though in such small quantity as to escape our notice.

Complete fallowing seems the most effectual method to get rid of the evil. The exhalation of the natural moisture opens the pores of the soil, for the admission of air; which, converting the sulphur into acid, renders it liable to be washed away by the showers that fall. In consequence of the swelling occasioned by the formation of the crystals of salt, the soil is more completely pulverized.

Mr. M'Kenzie, in the Appendix to Sir John Sinclair's Report of Caithness, &c. describes a method for aërating a soil, which certainly excels any other at present practised. This consists in fallowing by drills, in which only a third of the land is turned over at a time. Each fur-slice is turned over by the plough in alternate succession, and each is exposed a considerable time to the air, before it is covered by another laid upon its back.

But the most effectual method I can think of, for medicating soils of a thin staple, and *till* bottom, would be to plough them from ley as deep as possible: cut the furslices across into pieces about two feet in length, and build them up in long dykes, like those which compose a shepherd's fold. They should be built as open as possible, for the air to circulate through them, and in this position allowed to remain for two or more years. Meanwhile the subsoil should be turned with the spade, the stones picked out, limed, and laid in drills during winter. On these, cabbages or greens may be planted next season. Each year the drills should be reversed, and the same crop continued. The subsoil will thus be deepened, and completely medicated. Lastly the piled sods may be mixed with lime, and restored to their original position. This process would, in the end, be found the cheapest for some species of land that is to be reclaimed from its natural state; and where stones are wanted as facing to hedges, or to make roads, it would render the most sterile soil perfectly sweet and fertile. The way to proceed safely, is to do a small part in this manner, and then balance the profit with the expence.

The only other species of soil which I have found to contain ingredients hurtful to vegetation, is moss. The juice that is squeezed from some species of wet moss, yields a black precipitate with a solution of copperas. Water taken from a moss hole produces the same effect; though it is sometimes necessary to concentrate the water by boiling it in a glass vessel, to render the effect the more striking. These facts prove that moss contains a portion of galic acid, or astringent principle, a sub-

stance highly unfavourable to vegetation. To this cause we may impute its slow putrefaction, and its power of preserving animal bodies. As the putrefaction advances, a portion of this acid is evolved, and retards the putrefaction of the remainder.

Lime, and the alkalies produced in dung, operate as precipitates to the salts we have described. They absorb the acids, and render them harmless to vegetation. But it is previously necessary that the acids should be actually formed by exposing the soil to the air. The more caustic the lime is applied for this purpose, and the more completely it is mixed with the soil, the better. Caustic lime combines more readily with these ingredients than mild lime, and by their union a heat is produced, which serves to reduce and attenuate the soil.

We may therefore establish it as a general principle, that one great effect of lime, and other manures, upon a soil, is to absorb those acid ingredients which it may contain, and which operate as a poison to plants. They cause the soil to approach more towards the properties of alkaline, than of acid substances. This we may call medicating the soil.

Of Consistency.

It is not only necessary that obstructions to vegetation should be removed, but the consistency of the soil should be such, that plants can freely push their roots in it; while it still retains a sufficient degree of compactness to hold them firm. Aërating a soil by fallow reduces it to powder; but it again becomes hard after being drenched with rain, and dried. Lime and manures give the proper consistency to a soil. Lime renders a hard soil open, and consolidates one that is spongy and porous. It opens a hard soil, by appropriating its moisture, and entering into combination with it. A spongy soil is consolidated either by having its pores filled up, or if it be moss, by being corroded, or rotted into earth. For the first, and with a view to absorb the galic acid, lime should be applied as hot as possible. For the last, it is best applied in compost with earth. Earth or sand, of themselves, consolidate a mossy soil. The fermentation excited by lime and dung, the changes they produce among the component ingredients of a soil, preserve its porosity, and prevent its consolidation by drought. They also generate a heat which is independent of the sun's rays.

Retention of Moisture.

Manures farther render a soil retentive of moisture. The great fault of most soils is that they either retain moisture with too much, or too little force. A strong clay soil admits moisture very slowly; but what it gets, it retains with such force that an excessive heat is necessary to expel it. Clay consolidates with water into a hard body, which neither allows the roots of plants to push through, nor parts with moisture, for their nourishment. Lime, after its carbonic acid, and water of composition, are reabsorbed, readily admits, and freely parts with, moisture. It is therefore a proper corrective of the peculiar properties of clay. It also fills up the pores of sand or gravel, and corrects their defect of retention. Moss holds water like a sponge, and does not part with it except by evaporation. It is therefore always either too wet, or too dry for vegetation. Lime corrects this, by rotting it into vegetable earth, which, like itself, retains only the moisture necessary for vegetation. The salts and gases generated by the putrefaction of dung, also cause the soil to attract and retain the moisture necessary for vegetation. Putrefaction not only attracts and retains moisture, but also heats and modifies it for the subsistence of plants. A soil

that is well pulverized and manured, rejects all superfluous moisture which would prove hurtful to it. On the other hand, during drought, it appears in some measure deliquescent, and is moist when other soils are parched. Hence such a soil produces a crop in some respects independent of climate.

Fermentation excited by Manures.

We have all along taken fermentation in an enlarged sense, as applicable to every change which the component elements of bodies undergo when mixed with the soil. Thus the combination of acids and alkalies in a soil, or of acids and lime, is a fermentation. The effects which we, for the sake of perspicuity, have discriminated, go hand in hand. When acids combine with lime or alkalies, a great quantity of elastic vapour must be let loose; and by its expansion, enlarge the volume of the soil. Independent of this, we see that when lime is mixed with clay or earth, it causes them to swell into a larger size. This we may impute to its destroying their attraction for water, with which they shrink into a hard mass. The only exception to this is moss, which lime uniformly reduces into a smaller bulk, by rotting its vegetable fibres.

But the most sensible fermentation is excited in a soil by dung. Were this carried to excess, it would waste the moisture of the soil, cause it to heave, and throw out the plants. Were it too slow, it would not sufficiently attenuate the soil for the roots of plants to push through it. Hence dung is best applied after its first fermentation, which is most violent, is accomplished; and hence frequent turning the soil to the air, revives and prolongs the putrid fermentation.

That well manured earth swells and ferments by exposure to the air, appears from this, that rich earth (from a churchyard, for instance) cannot all be put back into the same hole from which it was dug; while poor earth never fills up the hole from which it was taken.

The addition of lime, and other salts, also revives and promotes putrefaction in a soil that had been impregnated with dung. For this purpose mild lime answers best; because in that state it is best calculated to promote putrefaction. Hence the propriety of allowing the lime, in powder, to remain some time upon the surface, to reabsorb its carbonic acid, before it mixes with the soil. Hence also for land that had been often dunged, lime is the best manure; and the contrary: but if they can be applied together, the most powerful effect ensues.

Washed soils do not seem to contain so much acid as those in their natural state. The soils too which are incumbent on basaltes, or whin rock, and which are composed of particles of the stone mouldered by the weather, seem to contain few or no ingredients hostile to vegetation, as they generally throw up sweet grass, even without ploughing or manures. Therefore less lime is necessary to medicate such soils. But a considerable quantity may be usefully employed to alter their consistency. Those which are composed of black loam, or mud, contain a large portion of vegetable matter in which fermentation has ceased, but may be revived by lime. On light sandy soils, lime seems chiefly to act in consolidating their parts; for such soils, from their porosity, admit air in such quantity, that dung is speedily fermented in them.

Hence clay soils should undergo a long course of cropping before they are thrown into pasture; and should, if possible, have a drill crop interposed between every two white crops; that by frequent turning up to the air, the fermentation may be carried to perfection. Hence light and porous soils answer best for pasture, that being con-

solidated by the tread of cattle, their too rapid fermentation may be checked. Hence also clay soils ought never to be touched by cattle during winter, or while they are soft by rain; while light, or porous soils, (moss excepted), are much improved by poaching after a drilled crop, or by cattle pasturing in winter.

If a soil be long exposed to fermentation, in consequence of repeated cropping, all the animal and vegetable matter in it will be exhausted; all the combinations which their principles can form, will be produced. No farther fermentation can therefore be excited, without a new addition of fermentable matter: the soil will become inactive, and unfit for farther production. The continued fermentation of animal and vegetable bodies, produces sulphur, which, as it becomes acidified, renders the soil unfit for the production of any but stunted and unsubstantial vegetables; when this happens, the soil is reduced to its original state of sterility. This last effect will not however take place, if the soil has been fully saturated with lime; for though such a soil should be rendered sterile, by exhausting its animal and vegetable ferments, it still retains the consistency produced by lime, and resists the accumulation of acid: the plants which it yields, will therefore continue succulent and palatable to cattle.

Lime is commonly esteemed an *alterative* manure; being supposed to act wholly in modifying the soil for the production of plants. Dung is reckoned to be the sole fertilizing manure, which supplies principles for the food of plants.

I am rather disposed to imagine that all manures act chiefly upon the soil, in the way here described; and if they supply any principles for the growth of plants, it is chiefly the gases which they evolve, and which enter the plants by their roots, or are absorbed by their leaves. That lime acts, indirectly at least, as a fertilizer, and can restore from the atmosphere animal matter, and thus excite a new fermentation after the soil is exhausted, appears credible from the following facts; in prisons, and houses where the air has been contaminated by animal exhalations, it may be rendered salubrious by white-washing the walls and floors with lime or chalk. In stables, necessaries, and rooms where animal exhalations abound, the plaster is frequently found to be incrusted with nitre; this can only be accounted for by supposing that lime has a power of absorbing animal exhalations, and causing a putrid fermentation, which terminates in the production of nitre: hence land that has been reduced to sterility by severe cropping after lime, may have its fertility restored by being kept long in pasture, with lime upon its surface.

It is a frequent complaint among farmers, that lime produces its greatest effect when first applied; but by frequent repetition begins to lose its power; this must necessarily happen, if what we have stated be true: but in so far as it operates as a ferment to animal and vegetable substances in the soil, this effect can only have place while there are such substances to operate upon. If they are exhausted, the soil should either be manured with dung, or allowed to rest.

I am disposed to think, that fertility may be restored to land which is exhausted by cropping, after being saturated with lime, not only by the addition of animal and vegetable manure, but also by restoring a portion of that very acid of which the lime had robbed the soil. Dr. Home, p. 90, informs us, "That a gentleman, with a view to destroy some rank grass in his court, was advised to sprinkle it with oil of vitriol; he did so, but, to his great suprise, the grass grew up much stronger than before." In this instance, it is more than probable the acid would meet with lime, or some alkaline substance, which would destroy its corrosive power; for no plant whatever will grow in contact with a strong mineral acid. To a soil saturated

with lime, but reduced to sterility, a small addition of acid would excite a new fermentation, by setting loose the carbonic acid connected with the lime; a substance highly favourable to vegetation.

From the remarks already made, we may perhaps be enabled to see why change of crop is so beneficial to land. Culmiferous plants, by the multiplicity of their small roots, bind and consolidate a soil, and check its fermentation: the roots seem also to remain inactive during the whole time that the seed is ripening; but leguminous plants continue to push their roots to the last. Red clover, beans, turnips, carrots, &c. being furnished with large and deep roots, penetrate and agitate the soil, and admit the air: they act in some respects, like the working of moles, or earth-worms; of consequence the fermentation is continued and re-excited, and the soil becomes better adapted for a crop of an opposite nature.

It would be an inquiry both curious and useful, to ascertain by analysis, the ingredients contained in all soils, fertile and sterile; and to mark the changes produced upon vegetation, by the addition of substances of every description. It would not be safe to embark in such projects on a large scale. Wooden boxes, or large earthen vessels, would be best adapted for trying the effects of manures of every species, and in every possible proportion; it would also be both curious and useful to investigate the proportions of the various primitive earths, that are best adapted to form receptacles for the production of plants. Chaptal informs us, that Mr. Tillet has proved, "That the best proportions of a fertile earth for corn, are three-eighths of clay, two-eighths of sand, and three-eighths of the fragments of hard stone."

These hints are thrown out with all the diffidence which is proper to be entertained by one who is duly sensible, that the facts are not fully investigated; if they lead to a more accurate investigation of the subject, the design of the author will be fully accomplished.

SECTION III.

Effects of Manures in the Production of Plants.

This part of our subject is involved in still greater obscurity than the former; it is more easy to mark the changes produced upon soils by working and manures, than to investigate the reasons why such changes render them more productive.

Many theories have been offered, by speculative writers, concerning the food of plants; the merits of which it is not our business to discuss. All that we propose is to recapitulate the leading facts, which have been ascertained by different persons, and suggest the conclusions which obviously flow from them.

That water is the principal nutriment which plants draw from the earth, by means of their roots, appears from the following facts.

"Van Helmont planted a willow, weighing fifty pounds, in a certain quantity of earth covered with sheet lead: he watered it for five years with distilled water; and at the end of that time, the tree weighed one hundred and sixty-nine pounds three ounces; and the earth in which it had vegetated was found to have suffered a loss of no more than three ounces. Boyle repeated the same experiment upon a plant which at the end of two years weighed fourteen pounds more, without the earth in which it had vegetated having lost any perceptible portion of its weight."*

Messrs. Duhamel and Bonnet supported plants with moss, and fed them with

* Chaptal's Chemistry, Vol. III. p. 23.

mere water. Mr. Tillet raised plants in a similar manner, with this difference only, that he used pounded glass and quartz as receptacles for their roots.

Plants which transpire much, have large and numerous roots, and absorb moisture from an extensive surface of earth. Mosses and lichens need little moisture, and have therefore few roots; and frequently grow on the surface of rocks. Plants imbibe moisture equally from their leaves and roots. Hence some aquatics have no roots, as the moisture is applied all round them.

That salts, oils, ardent spirits, or rather fluids different from water, form no part of the nutriment of plants, appears from the following experiments.

Mr. Duhamel * found from many experiments, that water impregnated with salts was fatal to vegetation. Mr. Hales made incisions in the roots of plants, and having plunged them in saline solutions, spirits of wine, and various fluids, found that these acted as poisons. Thouvenel and Cornette have proved that these salts do not pass into the vegetable. They seem therefore to operate as corrosives, or astringents, to close the mouths of the vessels, and prevent the absorption of water. Marine plants are an exception to this rule, which absorb sea-salt, and decompose it in their substance.

Dr. Home, indeed, found that various salts, and mixtures of salts with olive oil, † promoted the growth of plants. But we must ascribe the effects of such substances to their action on the soil, and not upon the plants. Whatever produces fermentation among the particles of the soil, must enable the roots of plants to extend more readily through it. All salts also render a soil more retentive of moisture; and if not of a corrosive nature, may serve as a basis for water, provided they be not in such quantity as to impede the absorption of the roots. Oils and mucilages seem only to act as ferments, and by putrefaction are resolved into their original elements. To this head we may refer the salts which are generated by the putrefaction of manures. These seem only to act by retaining moisture. It would appear, however, that the fermentive process, by which such salts are formed, operates a change upon the quality of the water, and prepares it for the subsistence of plants. We can form some idea of this by comparing it to the first process of digestion in the stomach, which animalizes the juices of the food, and prepares it for entering the absorbent vessels. Perhaps a part of this effect may be attributed to the heat which the fermentation generates, and to the gases which are evolved during the process.

Taking it then as certain that water is the chief, if not the only ingredient, which plants derive from the earth; and that manures only operate to prepare the soil for its reception, to retain and digest it for the roots of the plant: let us try to follow the progress of the juice, and illustrate the manner by which it is elaborated into the various products which plants afford.

That plants have a power of assimilating to their own nature, the raw materials that enter their bodies, and of elaborating the same species of matter into the different products which are yielded by the same, or different plants, appears from the following facts:

Trees that are grafted, or inoculated, possess not the qualities of the stock; but of the graft, or bud, that is inserted into the stock. Yet the grafted tree feeds upon, and absorbs the juices furnished by the stock. The fat plants which grow in a moist atmosphere without connection with the earth; those which grow in pure water, and the parasitical plants, which do not partake of the properties of those on which

* Chaptal, Vol. III. p. 25.

† Principles of Agriculture and Vegetation, p. 96, &c.

they fasten themselves: the various species of poisonous and nutritive plants which grow together on the same soil, and yet possess properties so very opposite, all these shew that the growth of plants does not depend upon any peculiarity of subsistence which each is adapted to imbibe from the soil; but that the matter furnished by the soil is the same to all, while the variations in the products are caused by the peculiar structure of each plant.

We may hence see the absurdity of those theories concerning the food of plants, with which so many volumes are stuffed; where it is frequently represented as a great magazine, or *pabulum vitæ*, originally created by the Supreme Being, and distributed in various proportions over the different districts of the globe. The alarms which these authors have attempted to excite lest this vegetable subsistence should, by the exportation of provisions, be exhausted in a particular country; and the various contrivances which some have hit upon to reimport this valuable matter, in the form of salts raised in vapour from the sea, or of chilling blasts from the frozen regions of the north, are equally curious and ridiculous. The ocean is the grand magazine of water, and consequently, of the food of plants for our globe. There is no great danger of exhausting this magazine, as what is taken from it returns in the course of circulation. The multiplication of vegetables has no other bounds, than the labour and ingenuity of man to prepare the earth for their reception.

The various products which vegetables yield are not so much varied in their composition, as we might, at first, be led to suppose. Thus oils, resins, and mucilage, consist almost wholly of hydrogen, or inflammable gas, one of the component parts of water. The different properties of these substances seem to arise from the various proportions of their component ingredients, or from their more or less perfect combination. The carbon, or charcoal, in plants, makes up the greatest part of the woody fibre; and this substance cannot possibly enter into their composition in any other form than that of carbonic acid, which combines with water, or floats in the lower regions of the atmosphere.

The way by which nature elaborates these various ingredients in plants, is by the action of the atmosphere, and of the sun's rays.

Mr. Hales first discovered the influence of air upon vegetation. Dr. Priestley opened a new career of discovery in this field, and illustrated it by a variety of curious experiments. He found that plants possess the power of absorbing the noxious gases which float in the atmosphere, and of rendering air pure and wholesome which had been vitiated by the breathing of animals, and the burning of fires. Dr. Ingen-housz pursued these inquiries with great ability and success, and has brought to light many curious facts in his *Experiments upon Vegetables*. The general result of them is, That plants immersed in water, in an inverted glass jar, and exposed to the sun's light, emit pure air, or oxygenous gas. The water here only serves the purpose of collecting the air emitted by the plant. He found also that plants possess a power of absorbing noxious gases in which they are immersed, and of substituting a portion of pure air. That this process depends upon the action of light; for in the dark, that plants emit noxious gases, though in much less quantity than the respirable gas emitted during the day.

M. Sennebier found that plants produce pure air by decomposing fixed air, or carbonic acid. That water serves as a vehicle to convey the fixed air into the plant. That plants immersed in carbonated water, and exposed to light, emit more pure air than in any other situation.*

* Annales de Chimie, vol. I. p. 114, 115.

M. Tukert, apothecary at Ingelfingen in Germany, watered one class of plants with distilled water; and another class, of the same species, with distilled water which was saturated with carbonic acid.

The germination and growth of the latter was more quick and vigorous, the flowers more beautiful, the leaves deeper coloured. The earth also that had been watered with the carbonated water, preserved its humidity much longer.*

The experiments, with a view to collect the gases emitted by plants, were commonly made upon leaves and branches detached from the stem. These were found to emit pure air during the day, and noxious air during the night. The sun's rays are capable of stimulating the vegetating process, by which pure air is emitted from plants, even in a branch that is severed from the stem: yet the process goes on much more rapidly in a plant that remains connected with its root. In a few experiments I have tried, the leaves and twigs of plants which continued connected with the growing stem, emitted about double the quantity of pure air, that was emitted in the same time, by other similar leaves and twigs, detached from the stem.

This excited a suspicion that the noxious air said to be emitted by plants during the night, might be owing to a commencing putrefaction in twigs and leaves severed from the growing stem. Putrefaction is precisely the reverse of vegetation, and restores to the atmosphere those gases which vegetation had absorbed. But that plants in a healthful and growing state, should at one period emit pure, and at another, noxious air, appeared to me a contradiction. I tried this by experiment, and found that growing stalks of strawberries, introduced into a glass jar filled with water, and inverted in a bason of water, emitted no air whatever during the night; but began to throw out small bubbles after the morning light began to break. The same stalks copiously emitted pure air during the day. Stalks of strawberries were selected for this experiment, because they admit of being bent, without danger of breaking their sap-vessels. They were introduced into the jar with a gentle bend, and so arranged that the stalk continued to adhere to its root, and was not broken or compressed in any part. A dark and cloudy night answers best for the experiment; for the light of the moon stimulates, in a small degree, the secretion of pure air from plants. We may therefore assume it as a principle that the secretion of air from healthful plants is merely suspended during the night, and that they emit none that is noxious to animal life. Hence the insalubrity of the air during night must be ascribed to the moisture which it then deposites; and not to noxious gases emitted by plants, which affect the lungs.

Besides the gas formerly mentioned, viz. carbonic acid, plants greedily absorb the nitrogen gas. This we had occasion to mention formerly, as forming the basis of the nitrous acid. About three-fourths of the atmosphere consist of this gas, and it is emitted in great quantity by putrid bodies. During this emission, if it comes in contact with an alkaline substance, or lime, it attracts oxygen, as we formerly mentioned, and forms nitre. But it seems to promote vegetation by entering the plant in its simple state. What office it performs, and how the plant elaborates it into subsistence, is unknown, as the composition of the gas is not understood. During putrefaction it is most copiously evolved from the mucilaginous parts of plants; and perhaps its presence is the sole cause why mucilages differ from oils.

Dr. Priestley placed plants in an atmosphere of this gas mixed with carbonic acid, or fixed air, so completely freed of respirable air that it killed animals, and extin-

* Annales de Chimie, vol. III. p. 300.

guished candles immersed in it; and found that the plants grew with greater vigour. By exposure to light, they soon decomposed the noxious gases, and produced such a quantity of oxygenous gas, that the atmosphere was restored to its respirable state.

It is of no importance where these gases are applied to the plant. Carbonic acid, being miscible with water, we may suppose enters partly by the roots. But it produces its effect equally well if applied, like an atmosphere, around the plant, especially if it be moistened by a gentle dew. Hence the gases which escape from a well manured field may operate in promoting the growth of plants, by absorption through the bark and leaves. If this be true, fermenting dung, or lime fermenting by an acid, as they emit a great quantity of gas, should promote the growth of contiguous plants, even though they come in contact with no part of them. It would be worth while to try this by experiment.

Plants seem capable of elaborating the mucilaginous fluid called their sap, by their own organic action, without the aid of light. But, without light, they form no principle capable of inflammation, and exhibit none of the properties peculiar to their species. Some of the fungi, indeed, grow where there is very little light; but they form no woody fibres unless exposed to that medium. If you place potatoes in drinking glasses, and water them occasionally, in a room that is sufficiently warm to promote vegetation, and into which light is only admitted through one small hole, they will push out strings, all converging towards the hole. When one is so fortunate as to get through, it immediately spreads its leaves in the air, and assumes all the properties peculiar to its species. All plants whatever, in similar circumstances, act in this manner.

The hop, and other climbing plants, always turn in the direction of the sun's motion. They all turn their flowers toward this luminary; and should a branch be bent so as the leaves may be reverted, they soon turn round, and regain their natural position. The economy of plants in this, and many other particulars, is so wonderful, that they seem actuated by a secret consciousness of the beneficent effects of light. Without the action of this fluid, though plants, at a proper degree of heat, can draw up juice, and extend in magnitude; yet they cannot fabricate any of those appropriated colours and products on which their specific characters depend.

M. Dorthes imputes the inclination of a plant, in a dark room, towards a hole through which light is admitted, to the pure air and water which light makes them exhale. This, he thinks, causes their growth to increase most on that side whereon the light falls; and thus to incline towards the aperture. But in the open air, as they have light on all sides, they affect a perpendicular posture. To this cause he likewise imputes the turning of flowers towards the sun. *

The sap is supposed to be raised in the plant by capillary attraction; though this supposition is attended with many difficulties, and it is not improbable that the vessels may be endowed with a vital action, similar to the absorbents of animals. The rise of the sap is promoted by heat, which also causes a great part to transpire through the leaves and bark. It seems analogous to the chyle of animals, and contains all the principles of the vegetable nutriment. From it the several organs elaborate those peculiar products which are found in the several parts of the plant. In order that we may form some idea of the manner by which this is effected, it may be necessary to enter into a short enumeration of the

* Annales de Chimie, vol. II. p. 98.

Parts, and Vessels of Plants.

A minute description of these belongs more properly to physiology, than to the object of this essay. We shall therefore content ourselves with those general outlines which are connected with our subject.

1. Plants are furnished with a hard fibrous mechanism, corresponding to the bones of animals. It is this part chiefly which furnishes charcoal when the plant is burnt; and it seems to be derived from carbonic acid decomposed by the action of light. The charcoal is fixed in the plant, the pure air rejected.

2. A cellular tissue which accompanies all the vessels, and envelopes all the fibres, corresponding to the cellular membrane of animals. In the cellular substance which lies within the outward coat of the bark, and where it is softer than in any other part of the plant, the business of digestion is chiefly conducted. Here the colouring matter of the vegetable is developed by the action of light, which penetrates the outward coating. Here also oils and resins are formed, by the decomposition of water and the carbonic acid. From this substance also the perspiration of the plant takes place; and superfluous water, aromatic oils, and pure air, are discharged, which are not necessary for the subsistence of the plant.

3. The sap vessels rise from the roots to every point of the bark and leaves. They also pass transversely into all parts of the plant. They are every where enveloped by the cellular substance, and act most powerfully within the bark. In the more interior parts of a tree they grow more and more rigid. The mouths of those vessels which terminate in the cellular tissue of the bark, present the sap, to the action of light, in an extremely divided state. By this mean pure air is secreted, and the sap rendered more inflammable. Whether the light, in producing this effect, enters into the composition of the plant, or merely acts as a stimulus to impel the organic action of the plant, is not ascertained. Plants imbibe moisture from the leaves and bark, as well as from the roots. Whether this is done by the sap, or circulating vessels, or if there be one set of vessels to absorb, and another to circulate the juice, as in animals, has not been ascertained. Nor is it certain if there be a returning circulation in plants, like the return of blood to the heart in animals furnished with lungs. There is only one fact alleged by those who maintain a returning circulation, and it is not decisive. A gash being made in a tree or other plant replete with juice, it bleeds more copiously from the upper, than from the lower part of the wound. A strong ligature being tied round a tree, it swells more above, than below the ligature. From above it projects bark, which in time covers the ligature, and incloses it in solid wood. This, they say, is like stopping a vein, by tying up the arm, which makes that part swell which is most remote from the heart; because it stops the blood which is returning to the centre of circulation. On the other hand, may not the fact be accounted for, by supposing that the sap descends more copiously from the upper part of the wound, from its gravity? And is it not probable that the accumulation of bark on the upper part of the ligature, may be owing to a rupture of the vessels? If this be true, both the examples are parallel: the bark increasing most where there is the greatest accumulation of juice.

4. Utricules and glands, are small vessels which receive the sap, and where peculiar juices are elaborated. These correspond with similar vessels in animals.

5. The tracheæ, or air-vessels. These answer the same purpose to plants, as lungs do to animals; though with this difference, that plants feed upon those atmospheric principles which are rejected by the lungs of animals, and would prove fatal to them.

The air-vessels correspond with the respiratory organs of certain insects, and open externally on every point of the plant; while they also pass, by innumerable convolutions, into every part of its interior structure; by these the plant absorbs the various gases that come in contact with it, mixes them with the sap, appropriates those that are hurtful to animal life, and rejects pure respirable air which supports life and flame. Perhaps the air-vessels may also serve the purpose of absorbents, and convey moisture into the plant. We already observed that noxious gases are most greedily absorbed, when the plant is gently moistened: it is very probable, that along with the gases inhaled from the atmosphere, moisture may also be conveyed.*

Many species of insects have no lungs, but in place of them, are furnished with air-vessels, which open externally on every point of them, and penetrate their interior structure, like those of plants. Tadpoles, and many flies in their vermiform state, seem to be constructed in this manner. Several insects have been found to thrive in an atmosphere of noxious gas, which would kill any other animal; and they rendered it highly respirable, by secreting oxygenous gas, like plants. We may hence see why many insects, and even fishes, live on nothing else but water, which they possess a power of decomposing, and convert the inflammable part to their nourishment; hence also many insects delight in putrid matter, where great quantities of noxious gases are emitted; these they convert, like plants, into sustenance, and reject the respirable part which sustains animals furnished with lungs. Were it not for the multiplication of insects, warm climates, where putrefaction is rapid, would be uninhabitable; the number of insects keeps pace with the putrid matter on which they subsist, and they absorb those noxious gases, which would otherwise render such climates the dreary abodes of pestilence.

In conducting experiments with leaves and twigs of plants, separated from the stem, it has been observed, that at first they emitted respirable gas; afterwards they began to emit noxious gas: but at length, began again to emit respirable gas more copiously than ever. We have already supposed the noxious gas might be owing to a commencing putrefaction in the leaf. But may not the ultimate emission of respirable gas, be caused by insects generated in the putrescent leaf, which absorb the noxious gases, and convert them into respirable gas. Sir Benjamin Thomson, now Comte Rumford, examined water, which had acquired a greenish colour during experiments of this kind, and found it full of insects: that which contained most insects, yielded respirable gas most copiously. This was done after the matter on which he was operating had remained so long in the water, that we might expect a putrefaction to have commenced. These conjectures are merely suggested to the attention of those who may have opportunities of ascertaining by experiment, how far they are well or ill founded.

6. The bark. This is the most important part of a vegetable, as in it all the secretions of respirable air, already described, are conducted: like the skins of animals, it invests all parts of the vegetable, both above and below ground; and like

* We can form some idea of the cause which impels aërial fluids into the interior parts of a plant, by supposing that they enter into composition with the sap; this must necessarily reduce their bulk, and occasion a constant pressure of the atmosphere through every pore of the plant, to supply the vacuum occasioned by the gases having passed into composition. The late Dr. Hunter also found that the internal heat of plants was uniformly greater than that of the atmosphere around them; a circumstance that must happen when gases enter into composition.

the former, it is composed of three coatings. In a healthy vegetable, the external coating of the bark is a transparent membrane, which defends the interior coating from injury, and admits the light to discharge the offices we have assigned to it; the second coating is very soft, and cellular, as we have already mentioned. Though the sap circulates in all parts of a plant, yet it flows most copiously in this membrane; and here it is presented to the light in the mouths of the sap-vessels. The third, or internal coating of the bark, is more rigid, and more replete with woody fibre. It hence follows, that trees must grow much more rapidly when they are kept clean on the surface. Lichen and moss, growing on their bark, must exclude the action of light, and stop both their inspiration, and expiration.*

Grasses and hollow plants, consist wholly of bark, without any ligneous part; in trees, the ligneous part is each year increased by the addition of the internal coating of the bark, which successively hardens into wood; thus the tree resembles concentric tubes, to which a new one is added each year, and which incloses all that were formed before; the middle coat, in its turn, assumes the place of the former. Trees soon die if the bark be stripped from them all round; unless the wood be defended from the air by a glass tube, or plaster of sufficient tenacity; if this be done, the outer coating gradually extends, and covers the wound; but the part never recovers the two interior coatings; this is precisely what happens when the wounds of animals are healed. Trees grow vigorously though they are rotten in the heart, provided the bark be sound; nay, from experiments made by the late Dr. Hope in the botanical garden at Edinburgh, it appears that trees will thrive though the wood be scooped out, provided the bark is not injured.

7. The leaves, are only an extension of the bark, to expose more surface to the action of air and light. The leaves of most plants seem to possess a muscular action, and hence close themselves during stormy weather, or in the absence of the sun. In some this power also resides at the junction of the leaf to the branch; in the sensitive plant, and a few more, it resides also at the junction of the branches with the stem: this muscular power does not seem to be exerted in consequence of an internal act of volition, but is impelled by external causes. Fair and foul weather, heat and cold, light and darkness, seem to be the principal causes which put in motion the muscular power of plants: perhaps they may also be affected by the changes which take place in the equilibrium of the electrical fluid; and which plants serve as conductors to convey into the air, or from the air into the earth; this circulation is seldom for a moment suspended.

8. The parts of fructification. These are invested with the flower, and consist of male and female organs, like those of animals. Flowers are endowed with a very delicate muscular power, and open or shut themselves with slight variations in the state of the weather; this seems chiefly to reside in the calyx, or husk, that incloses the flower: flowers also turn themselves towards the sun, as if to imbibe the rays of that beneficent luminary. Dr. Ingen-housz found that flowers always emitted noxious gases, both by night and by day; hence the danger of having flowers in bed-rooms, which has proved fatal to many.

When the fruit, or seed begins to form, the flower dies. Dr. Ingen-housz found that ripe fruits, of all kinds, emitted poisonous gases, in every situation; that nuts also, and beans, possessed this quality. Other seeds have not been examined, nor

* For the advantages arising from washing the stems of trees, see experiments narrated in the Philosophical Transactions for the year 1777, part I. p. 12.

has it been tried whether seeds and fruits emit pure, or noxious gas, at the different periods of their formation. If we may judge from analogy, we may be led to conclude that the husks, at least, of all seeds and fruits, should secrete a very respirable gas during the vigour of their growth; these are generally very cellular, and their office is to concoct juices for the supply of the seeds; in these the seeds are inclosed, like a fœtus in the uterus of its mother. The juices which are drawn up, and partially concocted in the body of the plant, are again concocted in this organ, for the nourishment of the seed; just as the blood of a female is prepared in the placenta for nourishing the fœtus; the seed, like the fœtus, seems to be nourished mostly by absorption, without any intimate connection with the husk. In wheat, and some species of corn, when the husk has discharged its office, it opens, and allows the seed to ripen by sun and air. In corn and culmiferous plants, the action of the roots seems to cease when the seeds begin to ripen; hence wheat and barley will continue to ripen after they are cut; provided the ears be laid upon the ground to imbibe the nightly dews, and frequently turned to receive the influence of the sun's rays during the day.

Lord Kaimes thinks, that the ripening of the seeds of plants, exhausts the soil; but we conceive that the fermentation of the soil ceases at this period, from the roots becoming inactive; and have assigned reasons why the fertility of land is prolonged by a variety of crops.

Some seeds of plants consist wholly of mucilage, others of mucilage united with oil. The farinacious seeds, under which we comprehend every species of corn and pulse; and to which we may also add potatoes, contain in various proportions, 1. Mucilage soluble in water; this is merely the sap of the plant, concocted and concentrated to the consistence of gum. 2. A resinous matter, called vegetable gluten, insoluble in water, inflammable like wax, in which oil predominates; this is merely the former matter farther concocted into an oily substance, by the decomposition of water; from which oxygen, or pure air, has been secreted; it contains also a portion of carbon: this very much resembles an animal substance, and is extremely disposed to putrefaction. 3. Fecula, or starch; in this carbon seems to predominate; and it is not inclined to putrefaction, except while it retains its natural union with the other ingredients.

These substances emit nitrogen gas by putrefaction, though we do not know the part it acts in their composition. The more perfectly the seeds are ripened, the more the two last products abound in them: this may naturally be expected, as they are formed by secreting pure air from water and carbonic acid, in consequence of exposing the plant to the sun's light.

The facts, of which we have attempted to present an imperfect sketch, must excite our wonder at the beautiful economy of nature. A subtile fluid, which plants reject as an excrement, being diffused through the atmosphere, is the only pabulum of flame, and breath of life to animals; without this fluid, all fires would be instantly extinguished, and all animals that are furnished with lungs, would drop down dead. On the contrary, the gases that are rejected as excrement by animals, and of which a certain quantity taken into the lungs, occasions instant death, being applied as manures to ferment the soil, or circulated in the atmosphere, are greedily absorbed by plants, and by them elaborated into subsistence for animals.

We may hence see one reason why the cultivation of the land improves the salubrity of a climate. Independent of the benefit arising from draining bogs and fens, which emit pestilential vapours; an active cultivation conveys into the soil all that

putrid matter, which, if allowed to accumulate, would taint the air; this, by the emission of its gases, shoots up into a luxuriant vegetation; which absorbs also those pernicious ingredients that casually float in the atmosphere, separating and rejecting from them the vivifying principle of animal life. By skilful cultivation trees and hedges are so arranged as to impede the fury of tempests; but not to prevent the moderate circulation of the air, or shade the cultivated land from the sun's rays, on which vegetation entirely depends; the whole country comes to be clothed with luxuriant vegetables, which are every moment employed in the purifying the air. In this view every vegetable, whether nutritive or poisonous, and however remote from human habitation, operates for the benefit of man; but its success in purifying the air, depends upon the luxuriance of its growth; the more therefore vegetation is promoted by cultivation, the more the air is rendered salubrious.

The conclusion which follows from these facts, is, that plants subsist wholly upon water, and those gases, or aërial fluids we have mentioned; which either float in the atmosphere, or are emitted by the fermentation of manures.

We would deduce a practical inference from these premises: that perfection of organs is necessary to the perfect growth of a plant; the quality of the organs will be determined by that of the seed. We all know how much various breeds of cattle have been improved, by successively propagating from the best of each species; now plants seem to depend more on the qualities of the parent stock, than even animals; might not then those stalks of corn be selected for seed, which are best headed, soonest ripe; and of these the best grains of each stalk? It would certainly be worth while to try if all the grains of a stalk answer equally well for seed, by planting out the top, middle, and bottom grains separately. A few handfuls of the seeds might be planted in rows, in the corner of a garden, and kept clean; those that answered best might be kept separate, and sown in the corner of a field; I would still continue to select the best from these as before; and by pursuing this plan for a course of years, it is impossible to foretel the perfection to which each species of seed may be carried.

It is well known that the best shoot of a potatoe comes from the highest eye; that one I mean which is most remote from the root, or filament, from which it grew: the stalks from this eye grow more rapidly, and produce more abundantly than any other eyes. Might not then these be always selected for seed, and the rest of the potatoe used for food? this eye might be occasionally cut out as the potatoes were used, and preserved among earth until the time of planting. This practice would probably extinguish the curl, for I never saw a stalk from this eye infected with that disease; I could adduce an example of this plan being actually adopted, which, as far as it has gone, has been attended with the most flattering success.

Those cabbages, carrots, turnips, &c. might be selected to produce seed, which were most perfect of their kind. For seed, the different species should be planted as remote as possible from each other. I have observed that the pollen of green kail, when the plants are mixed in the production of seed, sometimes impregnates cabbages, and produces a cross breed, more bulky than the kail, but which never forms a heart like the cabbage. Whether this takes place with any species of corn, I cannot affirm; but it seems to operate when different species of potatoes are mixed in planting.

By pursuing such experiments during a course of years, we may come to have various breeds of seed, equal in celebrity to the most renowned breeds of cattle.

As this Essay may fall into the hands of persons unacquainted with chemical terms, we have subjoined a short alphabetical explanation of such as are not illustrated in the Essay.

Acetous. Of or belonging to vinegar. Acetous fermentation, that which produces vinegar, or acid of wine.

Acid. Sharp, or sour, from the taste of such bodies. Oxygen united to an inflammable substance, forms an acid. Therefore, in the composition of all acids, one of the ingredients is uniformly the same. They are distinguished from each other by their basis, or the matter with which the oxygen is united; as sulphuric acid, from sulphur; carbonic acid, from carbon, &c. The number of acids has been prodigiously multiplied, from late discoveries.

Alkali. A simple salt, which, united with an acid, forms a neutral, that is, a salt which possesses none of the properties of the several ingredients in its composition. There are three species of alkali, vegetable, mineral, and volatile.

Animalized. Possessing the properties of an animal substance.

Basis. The matter which communicates to a compound its specific difference, is so called. Thus lime, alkalies, metals, &c. are the bases of all the salts formed from them.

Carbon. The matter of which coal or charcoal is chiefly composed.

Carbonic acid. Is also called fixed air, or aërial acid. It consists of oxygen united to carbon, and is produced by burning charcoal in contact with common air. It is emitted from the lungs of animals, where the oxygen of the atmosphere combines with carbon in the blood, and supports the animal heat. Vast quantities of it are emitted from fermenting vats, and from putrid bodies. It is called choak-damp by miners, because it extinguishes candles, and frequently kills persons immersed in it. Animal life and flame it suddenly extinguishes, if taken into the lungs; but is salutary when taken into the stomach. Fermented liquors owe their briskness to this gas; and like most other acids, it always appears in the form of a gas, unless when it enters into composition with other bodies. United with lime, it forms a part of the solid stone, and renders lime and alkalies mild, that is, neutral salts. Though an acid, it has hardly any corrosive power. It is absorbed by plants, which retain its carbon, or inflammable basis, and reject its oxygen or pure air. It is heavier than common air, and therefore always floats in the lower parts of the atmosphere.

Caput mortuum. The residue after a chemical process is completed, and which does not admit of farther change by the means that are used, is so called.

Crystallization. A process by which bodies pass slowly, and without disturbance, from a liquid to a solid form. When this happens, all bodies assume a peculiar, and regular arrangement, both in their internal particles, and external figures. The bodies are then said to be crystallized, and the figures they assume are called crystals. The term is frequently applied when bodies consolidate, without any apparent regularity of figure.

Effloresce, Efflorescence. When salts, mixed with earth, crystallize by the action of the air, they are said to effloresce; because the product has often the appearance of vegetable flowers.

Gas. Any fluid, which is permanently elastic, or which cannot be reduced into a liquid by cold, is so called. Steam resembles gas in elasticity; but is again reduced to liquid by cold. Gases, being transparent, cannot be perceived by the eye, and can only be distinguished by their effects upon bodies. With regard to their effects upon the human body, there is only one, viz. oxygen, which supports respiration. All others, when taken into the lungs, without a proper mixture of this gas, prove fatal, and some almost instantly. In this view, such are called *noxious gases.* But this term does not imply that such are hurtful in every mode of application; for many of them are salutary when conveyed into the stomach. The atmosphere is the grand magazine of the gases.

Gastric juice. Is secreted in the stomach, and is the cause of digestion. It dissolves all animal substances, except those which are alive, or putrid; all fruits and seeds of plants; but never touches their skins.

Gelatinous. Possessing the properties of a gelly, or animal extract.

Hydrogen. A gas, also called inflammable air, because it takes fire. Miners call it *wild-fire,* because it produces dreadful explosions when great masses of it are incautiously set on fire. During its inflammation it combines with oxygen, and forms water; and hence it derives its name. Water was formerly supposed to be a simple elementary body; but is now found to be a compound. Plants decompose it by absorbing the hydrogen, and rejecting the oxygen.

Latent heat. That which enters into composition with a body, and no longer effects our senses. This is again emitted, or becomes active, when the body suffers a change of form, by passing from a more rare, to a more dense combination.

Mucilage. Of this there are two kinds. One that dissolves both in hot and cold water, of which gum Arabic is an example. Another that dissolves in cold, but coagulates in hot water. Whites of eggs are an example of the last; and both kinds are found in vegetables.

Nitre. Called also salt-petre, is a salt formed during the putrefaction of animal and vegetable substances. It consists of three ingredients, nitrogen gas, oxygen, and vegetable alkali.

Nitrogen gas. Called also azote, and mephitic gas. Is the basis of the nitrous acid, and of volatile alkali. This gas is absorbed by plants during vegetation, and emitted again during putrefaction. It constitutes three-fourths of the atmospheric air. It speedily kills an animal when taken into the lungs by itself, and extinguishes flame. Its use in the atmosphere is to modify, and dilute the other gas, viz. oxygen, of which one-fourth part of the atmosphere is composed. Were the atmosphere wholly composed of oxygenous gas, the heat of fires would be terrible, and unextinguishable; and animals would always possess the heat of a raging fever.

Neutralize. To destroy the corrosive power of a body, or its tendency to combination.

Neutral salt. Is one that has no corrosive power. Acids and alkalies, when pure, have a strong tendency to combine with bodies. When united, this tendency is destroyed, and of consequence, they have no longer a corrosive power. The combinations of alkalies and acids, from the strength of their union, are called perfect neutrals. The combinations of acids with other bodies, being more easily destroyed, are called imperfectly neutral salts.

Oxygen. Is a gas, and is also called pure air, or respirable air. It is called oxygen, because its union with certain bodies renders them sharp, or sour. It is the cause of acidity in all bodies; the sole cause of inflammation, and of animal heat, by means of respiration in the lungs. About one-fourth part of the atmosphere is composed of this fluid, and it is constantly emitted by growing plants when exposed to light. When this gas combines with a body, it deposites heat; of which it contains a great quantity.

Phosphoric acid. Oxygen and phosphorus united. Phosphorus is an extremely inflammable substance, and takes fire at the heat of the human body. By burning, it is converted into acid.

Neutral salts. Those that had no corroding power. Acids and alkalies, when pure, have so strong tendency to combine with bodies. When united, this tendency is destroyed, and of consequence, they have no longer a corrosive power. The combinations of alkalies and acids, from the strength of their union, are called perfect neutrals. The combinations of acids with other bases, being more easily decomposed, are called imperfectly neutral salts.

Oxygen. This fluid is also called pure air, or [illegible] air. [illegible] oxygen, [illegible] in bodies renders them sharp, or sour. [illegible] cause of [illegible] bodies; the sole cause of inflammation, and of animal heat, by means of respiration in the lungs. About one fourth part of the atmosphere is composed of this fluid, and it is constantly emitted by growing plants when exposed to light. When this gas combines with a body, it [illegible] of which it contains a great quantity.

Phosphoric. Oxygen and phosphorus united. Phosphorus is an extremely inflammable substance, and takes fire at the heat of the human body. By burning, it is converted into acid.

No. V.

Letter from Dr. GUTHRIE of St. Petersburgh, To Sir JOHN SINCLAIR, Bart. P. B. A. On the Subject of Manures.

DEAR SIR,

I AM much flattered with your obliging letter, more particularly with that part of it in which you desire my remarks on the valuable and able didactic Report to the Board of Agriculture on Manures.

But you seem to forget, good Sir, that although I may occasionally treat subjects of agriculture from its connection with chemistry and natural history, my favourite pursuits, yet confinement by professional duty for a number of years to a small circle round the new capital of Russia, must make my practical knowledge of that most useful of all sciences, nearly as confined as my range.

However, if you will accept of a few observations on what may be called the philosophy of agriculture, and the principle on which manures act, they are much at your service; and they will at least have the merit of brevity, being condensed into the compass of a letter.

First, I shall only observe on agriculture in general, that the beautiful and simple system of the great Swedish naturalist, Bergman, (which the report seems to attribute to Kirwan, our own great chemist) was founded on the well known fact, *that plants will grow in water alone*;* and therefore, considering the nourishment of plants as derived solely from that element, he concluded that the whole business of agriculture must be, to prepare the soil in such a manner, as merely to retain just as much *water* as is necessary for their subsistence and no more, as a superfluous quantity serves to chill and rot them.

In this view of the subject, the farmer was to correct the loose porous nature of a sandy soil, which lets all the water run through it, by adding clay to make it more stiff and tenacious; whilst, on the contrary, he was to add sand to stiff clay, to make it less tenacious and retentive, as such kind of ground retains too much water.

Certainly nothing could be more clear, simple, and philosophic than this system; and it is equally certain, that the learned Swede taught nothing but truth, although he neglected to teach all the truth, for although plants will grow in water alone,

* I have noted somewhere in my papers, but cannot lay my hand on it in the moment, a famous experiment (made I think in Holland) to determine this curious fact, where a young tree weighing only *a few ounces*, was planted in a jar of water, with some clean sea-sand at bottom to hold it upright; and although it never was supplied with any other nourishment *but pure water*, it weighed, when cut down some years after, several hundred pounds, as far as I can recollect.

still they grow more luxuriantly when supplied with a species of nourishment named by chemists mucilage, obtained by putrefaction from all kinds of animal and vegetable matter.

This fact renders the study of manures an essential part of agriculture, even after the soil has been already prepared on professor Bergman's principle, so as to retain the necessary quantity of water, and to yield readily to the shooting of the tender roots of the crop, without excluding the action of the air upon them, so necessary to vegetation.

The best way then of obtaining and applying the production of putrefaction, so essential to the nourishment of plants, is the subject of the judicious Report to the Board, which you was so kind as send me, and on which I shall take the liberty of making a few observations.

When this mucilage is to be prepared from manure before laid on the ground, according to the excellent instructions given in the Report *for the Management of Dung-hills*, care should be taken that the stage of putrid fermentation is not allowed to run too far after the separation of the mucilage, as that valuable matter, the object of so much expence and care, will be converted into salts and earth * by a continuation of the intestine motion that produced it.

It appears, therefore, that a criterion to judge when the mucilage is prepared and the putrid fermentation ought to be stopped, is a desideratum in this branch of economics.

One observation on this subject, I think may be boldly hazarded, which is, that as long as a dung-hill is *hot*, there is no danger of the accident happening, as heat is only produced by the three first stages of fermentation, viz. the saccharine, vinous and acetous, the fourth, or putrid, generating none.

Possibly practical men may be able to determine, *by the change of smell*, when the putrid fermentation is passing on to the decomposition of the mucilage it has formed; but surely it must always be erring on the safe side to employ the dung rather too early than too late, as what is wanting of the process may be carried on in the ground; whereas if it is already converted into salts and earth, nothing can recover it.

But when, on the contrary, it is intended to convert into mucilage, matter already artificially mixed with, or naturally contained in the soil, (which I suspect to be the case with the rich lands in Italy, from Dr. Scandella's asserting, that foreign manure without nourishment was all they require, for such is the only construction that can be put on his paper) I say, when this is intended, certain substances are laid on the soil to promote the same putrefaction in the earth, which was in the last effected in the dung-hill.

These forcing manures, as they are very properly called, are the neutral salts with calcareous earth, either pure or mixed, as in marl; even lime, five or six months old, comes under this last head, as it has absorbed from the atmosphere the fixed air it lost in burning, and is once more become a mild calcareous earth, disposing to putrefaction. The most common and cheapest of the earthy neutral salts, and therefore most used as a forcing manure, is gypsum, or plaster of Paris.

* To attain the very end which should be carefully guarded against in the preparation of manure by fermentation, seems to be the sole purpose of Dr. Scandella's paper given in the Appendix to the Report; and affords a strong proof of the necessity of the caution I have given above, as he evidently shows that salts and earth will be the result of prolonged fermentation in a dung-hill, and that the valuable mucilage, I am treating of, will be destroyed, a substance however, which the writer seems to be unacquainted with.

There is still another class of forcing manures, which, although they do not prepare the food of plants, *by forwarding putrefaction*, like the last, yet they still prepare it in another manner.

These are alkaline salts and quick lime, which render all animal and vegetable oils of a saponacious nature, so as to dissolve readily in water, and thereby fit them to enter the vessels of plants, which they cannot do in their natural state, probably from its clogging up the fine capillary vessels, so as to prevent vegetables absorbing water and mucilage.

This last class of manures has likewise the good effect of killing insects, which are then converted into mucilage, and of decomposing poisonous metallic salts, particularly pyrites, the most common in soil, and thereby rendering them rather useful than hurtful to the crop, for whilst the metallic part is precipitated in a harmless mass, the disengaged acid may form useful neutral salts with the alkali or calcareous earth. They also correct acidity in the soil when it attains; and in that case may likewise form the same kind of active compounds with the superfluous acid as in the last.

Such, Sir, is the doctrine taught by chemistry relative to the action of the two classes of forcing manures employed in agriculture; but they seem still to have another operation, on which that science is silent, viz. that of *stimulating vegetable life*, which we know so very little about, that I shall only venture one hint on the subject at the end of my letter, when speaking of irrigation.

As to the principle of fallowing—I should think that tedious process can have no other effect than that of converting weeds, and other corruptible matter contained in the soil, into mucilage, (if it actually destroys their vegetable life) and that of exposing to the air for decomposition, hurtful metallic salts, if the ground is infected with them. But in poor sand, where there is little vegetable matter to rot, certainly fallowing can be of little service; whilst one is disposed to imagine, that if the same end can be accomplished by manures, or enriching crops, which leave much vegetable matter in the earth, it must be a great advantage to agriculture to gain the year's use of the soil which is lost by fallowing.

Paring and burning is a practice which seems to require very serious consideration, as certainly the small quantity of alkaline salt, obtained at such a loss of vegetable matter, which might have been, by proper management, converted into the nourishment of plants, is evidently a losing calculation; nay, I do not well understand what is left in the soil for this small portion of dear bought forcing manure to act upon, except the operation is performed upon a rich virgin soil, where none of the two classes of forcing manures mentioned above are to be had.

The last operation in agriculture which I shall here take notice of, is the system of irrigation, or manuring land by flooding it for a time.

That most excellent mode of fertilizing ground, I am not surprised to hear, comes but slowly into general use in Britain, as it must be difficult to convince men who have not seen its effects, that so limpid and pure a fluid as water should contain such a quantity of vegetable nourishment, especially as the wonder is rather increased than diminished, when we call in the aid of chemical analysis to explain the mystery.

The water of the river Neva, for example, which runs through this city, has been lately examined by Mr. Georgi, professor of chemistry in the Imperial Academy of Sciences (as it had been formerly by the great Moddel) and he only found in 50 pounds of it, taken up in the middle of the town, 40 grains of mild calcareous, and 5 of vegetable earth, with a very little common air—or not one grain of heterogeneous

matter to a pound; an impregnation that by no means accounts, neither for its strong purgative effects on strangers, often very severe for the first 8 or 10 days, nor would it for its fertilizing powers, were its waters judiciously employed for the purpose of manuring fields, which there cannot be a doubt of its effecting in common with all the other rivers in the world.

Here is then one of the most evident examples of a very pure water acting as a *stimulus* on the human body, in a way we cannot explain; for surely the trifling admixture of a grain of inert and innocent earth can never account for its powerful operation as a purgative; nor do I think that we could attribute to so small a proportion of solid matter its manuring land, if it was employed in agriculture, so that we must suppose that water has likewise stimulating effects on plants.

This conclusion, I flatter myself, you will allow to arise naturally from the analysis and operation of our Neva water, the only river I have had an opportunity of making constant remarks upon for a number of years, or I would not have ventured a conjecture on so obscure a subject as the principle of irrigation; which, however, I submit, with all the others, to the judgment of the Board of Agriculture, only sorry that I have nothing else at present to offer it, but the profound respect and best wishes of, dear Sir,

Your most obedient humble Servant,

MATTHEW GUTHRIE, M.D.

Imperial Corps of Noble Land Cadets in St. Petersburg.
October the 30th, 1795.

No. VI.

On the Use of Lime as a Manure; extracted from a Letter dated Lancaster, December 7th, 1795.

I YESTERDAY saw a very intelligent farmer, who lives in the neighbourhood of *Ellell Moor*, (the common you allude to,) and find the general fact, that it was *limed*, and, that a great part of it was, and perhaps still is, little better than a *caput mortuum*, to be true. But however improper lime may be on certain soils, and in too great proportion, the present instance will, I apprehend, only prove that lime is not adequate to compensate for natural defects, and bad husbandry united. The situation of great part of the Moor is high, cold, and exposed to the west winds; the soil is an ochrey clay, mixed with sand, and in many parts very shallow over a coarse mill-stone-greet rock; and produced, before it was inclosed, little more than ling (heath), and rushes. Being pared and burned before it was ploughed, it produced exceeding good crops of corn for *a year* or *two*, or even *three years*, in some parts of it; but there being a clause in the inclosure bill, which *exempted them from tythes for seven years*, it occasioned such a spirit for *ploughing*, and getting what corn crops they could during that period, that the ground became quite exhausted; and was by this means reduced to a state which will require many years of rest, or a considerable quantity of the richer manures, to restore it.

I do not apprehend, that there is much danger of a deficiency of vegetation being occasioned in this country, from any over proportion of lime being applied; the quantity which is generally used within a few miles of the kilns, at Kellet; is from 250 to 300 Winchester bushels, stroked measure, per acre; and there would be little cause to suspect, that this quantity was exceeded in the case of Ellell Moor; as they would have to fetch it at least ten miles, and it would cost them sixpence the bushel on the ground. Now the Bishop of Llandaff tells us, that he has known a gentleman in Derbyshire, who has frequently with great success, spread 1000 Winchester bushels of lime on an acre of ground, a proportion that has never been tried in this country, that I know of; the greatest quantity, that I have ever heard of, was on a field or two, about two miles north of Lancaster, where 420 bushels were spread per acre; it was near a year before the land was perfectly coated over again: but I have observed, that it is the earliest in vegetation of any in the country, ever since.

The soil in this country is mostly a stiff loam, or clay, which being mixed with lime, either as a compost for corn, or spread on grass lands, has a tendency to render the soil more fertile in those vegetables which are useful in our domestic economy; which I should apprehend it does in two ways, first, by mixing with and mechanically dividing the stiffer soils, and thereby facilitating the passage and growth of the fibrous roots of grasses, and similar vegetables; and secondly, by connecting an *ascescent* quality, which occurs in these soils. That lime, when used fresh from

the kiln, will destroy vegetable life, and by that means occasion a putrefaction of such substances, there can be no doubt: but I think there is reason to question, whether this be the sole mode by which it becomes useful as a manure; for it will in the course of a very few days lose all its caustic properties, and become in fact nothing more than calcareous earth finely divided; in which state it is mixed with the earth, and forms that soil which is favourable to the growth of the grasses, and other plants, which are nutritive to the animals we wish to feed. That changes in the component parts of the soil, as to their proportions, as well as their natures, will occasion plants of different kinds to make their appearance and thrive there, we know by daily experience. I shall instance two with respect to lime. When a field has been long pastured, it will become covered with *moss*, which, although it does not prevent grass from making its appearance, and growing through it, yet very much reduces the quantity of the crop. Lime spread on a field of this description will occasion an increased crop of the grass; much white clover, and the moss will disappear. On any of the high lands in this country, which produce only a hard and tough acerb grass, which cattle will scarcely touch, if lime be spread, this kind of grass will disappear in a great measure, and in the place thereof will come up other grasses, and particularly white clover, which cattle will eat even to the roots. It would appear that in these instances, by the addition of lime, a particular soil, (like the *tertium quid* in chemistry) is produced, that is favourable to the growth of the grasses which are found by experience to be useful; and unfavourable to such vegetables as we wish to get quit of, as we see happens in the case of artificial grasses, which continue only for a year or two, and are then overpowered, and extinguished by those more suited to the soil.

It has often been a matter of surprise how the *white clover*, which follows the application of lime, is produced where none is sown. Is it that the seeds of plants are very generally distributed in the earth, and that they remain in a state not liable to decay, until a soil favcurable to their vegetation occurs? or, are their seeds carried annually by the winds, and deposited through the country, but only vegetate when they meet with favourable circumstances?

On the Use of Coal Slack by itself, and mixed with Lime;

By Richard Crawshay, Esq.

Parish of Myrther, Glamorganshire.

ABOUT four years ago, I tried the following dressings of a piece of meadow land; quantity about eight acres. The whole field is equally a dry scil, the form oblong, lies on a hill-side, dipping from west to east. I divided it into three parts thus, and manured as under.

No. 1.	No. 2.	No. 3.
Stable-muck mixed with braes, a small coak, which drips from the air furnace grates.	Wholly the slack of coals, that we generally throw away in large quantities.	Half lime, mixed with road or pond dirt.

No. 2. exhibited grass like a green riband, before the others shewed any spring; No. 1. followed; No. 3. was last, and proved the smallest crop of hay. Since that time I dress the dry lands every year with the coal slack alone, or mixed with lime; and have better crops than formerly, from the same lands, which are very poor, and used to give only short hay fit for cows, I now carry from 20 to 30 *Cwt.* of good horses' hay, and have the stable muck left for the ploughed lands. On wet and boggy soils, I find the braes mixed with lime, answers better than any other dressing we have; the braes, where there is a fall on lands, (*i. e.* an inclined plane) make the best drain in the world, thus,

On these poor hill-sides, which are the tumble-down of the mountains, more of stone than soil, when I break up first, the crop is oats, or oats with vetches for green fodder in summer, or hay if the season will permit; second, wheat, winter fallow and dressing; third, barley with clover; fourth, clover, winter fallow, well dressed, vetches with oats; these I believe are the only fallows needful; the lands with us should after this product be laid down with seeds.

Derbyshire Mode of using Lime, for improving Heathy Land.

IN regard to laying lime on heathy land; first pare the ground in the beginning of March about one inch and a half thick, turn it about in dry weather; when dry, gather it into rucks and burn it into ashes; spread them even over the ground: then set 6 score of lime on every acre, spread it as before, then harrow it all together; and then plough it very thin, and sow it with turnips, or rape; then the spring following sow with oats, or barley, and good grass seeds; then another good dressing with lime after the first crop of seeds is got; and then it may lay for pasture. The above is the best method in this country.

On the Improvement of Moors and Heath Land, by Liming the Surface, as practiced near Buxton in Derbyshire; extracted from a Letter, dated 16th March, 1796.

NO country has experienced greater advantage than this in the improvement of common moor land, by lime laid on the surface. The quantity laid on a statute acre of common land, where it is covered with strong heath, bent, or ling, is four

hundred bushels of good lime, at two-pence farthing per bushel at the kiln, will cost £ 3. 15s. the whole expence of which, with the carrying it out, and spreading, will amount to £ 5. per statute acre. The lime-stone quarry is upon the land that is improving; and the coals are from two to three miles distance. I have sufficiently experienced that spreading the lime in a slacked state is by far the best method.

As to the season of the year, the summer months are preferred, because the fewer coals are necessary for burning; but for no other reason are they preferable to the winter months for laying the lime upon the ground.

The annual return to the owners of the land is seven and eight per cent.; but there are many instances of much more being paid, besides the original value of the land, which is from one to three shillings per acre per annum.

I have ploughed common land, and let it remain in that state twelve months, and then laid it down with grass seeds, without lime or any other manure; and have found the land to be of three times its former value. If that method were practiced upon large commons, three times the number of sheep or other cattle might be kept on the same land.